



Europäisches Patentamt  
European Patent Office  
Office européen des brevets



(11) Publication number : **0 265 178 B1**

(12)

## EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification :  
12.04.95 Bulletin 95/15

(51) Int. Cl.<sup>6</sup> : **H04B 7/185**

(21) Application number : **87309122.7**

(22) Date of filing : **15.10.87**

(54) **Spread spectrum multiple access communication using satellite or terrestrial repeaters.**

(30) Priority : 17.10.86 US 921261

(43) Date of publication of application :  
27.04.88 Bulletin 88/17

(45) Publication of the grant of the patent :  
12.04.95 Bulletin 95/15

(84) Designated Contracting States :  
AT BE CH DE ES FR GB GR IT LI LU NL SE

(56) References cited :  
DE-A- 1 804 811  
DE-A- 2 245 341  
GB-A- 1 502 253  
US-A- 2 678 998  
US-A- 4 379 296  
NATIONAL COMMUNICATION CONFERENCE  
RECORD '77, vol. 2, December 1977, pages  
19:3-1 - 19:3-7, IEEE, New York, US; W.A. IM-  
BRIALE et al.: "An S-band phased array for  
multiple access communications"  
PROCEEDINGS OF THE IEEE, vol. 66, no. 11,  
November 1978, pages 1468-1496, New York,  
US; R.E. KAHN et al.: "Advances in packet  
radio technology"  
FREQUENZ, vol. 40, nos. 9-10, September/Oc-  
tober 1986, pages 255-259, Berlin, DE A.  
EIZENHOEFER: "Anwendung der spread-  
spectrum-technik in dem hybriden mobilfunk-  
system MATS-D"  
PATENT ABSTRACTS OF JAPAN, vol. 9 no.  
291, (E-359)(2014), November 19, 1985; &  
JP-A-60 130 931 (NIPPON DENKI K.K.) 12-  
07-1985  
SIXTH INTERNATIONAL CONFERENCE ON  
DIGITAL SATELLITE COMMUNICATIONS,  
September 19-23, 1983, pages IX-21 - IX-28,  
New York, US; T. WATANABE ET AL.: "Site  
diversity and up-path power control experi-  
ments for TDMA satellite link in 14/11 GHz  
bands"

(56) References cited :  
IEE PROCEEDINGS, Section A à I, vol. 131,  
Part F, no. 1, February 1984, pages 87-91, Old  
Woking, Surrey, GB; R. SKAUG: "Experiment  
with spread spectrum modulation on an HF  
channel"  
IEEE TRANSACTIONS ON AEROSPACE AND  
ELECTRONIC SYSTEMS, AES-22, no. 3, May  
1986, pages 281-290, New York, US; N.  
HAMAMOTO et al.: "Communications Experi-  
ments: Spread Spectrum Multiple Access"

(73) Proprietor : QUALCOMM, INC.  
10555 Sorrento Valley Road  
San Diego California 92121 (US)

(72) Inventor : Gilhousen, Klein S.  
4039 Calgary Avenue  
San Diego California 92122 (US)  
Inventor : Jacobs, Irwin M.  
2710 Inverness Court  
La Jolla California 92037 (US)  
Inventor : Weaver, Lindsay A., Jr.  
3419 Tony Drive  
San Diego California 92122 (US)

(74) Representative : Dempster, Benjamin John  
Naftel et al  
Withers & Rogers  
4 Dyer's Buildings,  
Holborn  
London EC1N 2JT (GB)

EP 0 265 178 B1

Note : Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid (Art. 99(1) European patent convention).

## Description

The present invention relates to multiple access communication systems and more particularly to a method and apparatus for employing Code Division Multiple Access (CDMA) spread spectrum signals to provide communication services for mobile or remote user terminals using satellite or terrestrially based repeater apparatus. The present invention further relates to utilizing CDMA spread spectrum signals with multiple beam phased array repeater antennas, polarization enhanced omni-directional mobile antennas, voice or data activity switching, adjustable user terminal power control, and L frequency band communication links.

There has been a long-standing need to provide quality communication services to many groups of service users that are classified as remote or mobile or both. These users include rural telephone systems, police and other governmental agencies, commercial dispatching and paging systems, emergency services, and marine telephone. In the past these needs were partially satisfied by land mobile radio. However, these services have always been faced with more potential users than system capacity. The frequency or spectral bandwidth allocations do not provide enough capacity to simultaneously handle the total number of potential users.

Even so, private individuals, businesses, and new classes of users, such as aeronautical communications, are creating an ever increasing demand for services for both mobile and remote users. A large increase in the number of remotely accessible computers and data systems has also created a demand for remote and mobile digital data communications in addition to voice communications. In addition, new types of remote data collection or sensing, and alphanumeric keypad or keyboard entry systems are being proposed which can not be serviced by current communication systems. Therefore, new communication systems are being proposed and built to serve these demands for service.

In building or implementing any new communication system, the key issue for both the designer and the end user is the channel capacity of the system. In a commercial system, capacity translates directly into income or economic feasibility which is important to the system operator, since capacity determines the number of revenue generating users that can be accommodated. The number of allowable users is in turn important to the potential service users. The number of simultaneous users and, therefore, capacity supported by any communication system is determined by the amount of mutual interference between users.

Current mobile radio services operate as frequency division multiplexed (FDM) or frequency division multiple access (FDMA) systems which divide the available bandwidth into smaller bands or channels. To decrease mutual interference some of the bandwidth is also assigned to "guard bands" between channels to provide attenuation or isolation between users. Full duplex communication requires two channels. The total number of channels is generally divided in half, one half being for uplink and call control to a central base repeater and the other for downlink and control signals to users. In addition, some channels may be allocated for additional user protocol and call control. Therefore, the number of simultaneous users is much lower than the apparent number of channels.

System capacity can be increased by increasing the number of channels but this decreases channel bandwidth which limits voice quality and the use of high speed data transfers. Instead, the preferred technique for increasing system capacity is frequency reuse. Frequency reuse is the process of using the same frequency in two separate geographic regions for two distinct communication links as long as the two regions are attenuated or isolated from each other by a minimum value for signal rejection by the two user receivers.

Typical isolation or attenuation requirements for adequate rejection of unwanted signals are on the order of 15 dB (FM type) to 30 dB (AM) or more down from the desired signals. Therefore, a communication system can be sub-divided into geographical regions and the same frequency can simultaneously be "reused" in neighboring regions which are isolated from each other by the appropriate attenuation. This technique is easily applied in land mobile radio systems since radio waves are inherently attenuated proportional to the square of the distance from the radiating source (in free space). Systems operating in large urban areas actually appear to experience  $1/r^3$  to  $1/r^6$  attenuation due to buildings and other absorbing structures.

Users geographically removed from each other by an appreciable distance naturally have their communication signals attenuated with respect to each other. Therefore, a communication system can be constructed using several interconnected base stations positioned so that signals from adjacent stations experience a 15 to 30 dB attenuation with respect to each other. To further increase capacity the geographical regions served by base transceivers are divided into successively smaller sized which are separated by the appropriate attenuation or isolation, to allow for increased frequency reuse.

This is the basis for cellular telephone technology which is the current approach to accommodating large numbers of mobile users. Here, each cell comprises a geographical region serviced by a central base station which uses land based communication lines and switching systems to form an interlinked system with other base stations so that the only airborne transmissions are localized across the cell. To decrease mutual interference and increase system capacity, frequency use is controlled to assure a minimum amount of isolation

between users by assigning channels so that at least one "guard" cell is positioned between two users using the same channel. Each cell is large enough so that signals crossing a cell are attenuated a substantial amount so that they are perceived as lower level noise in distant cells. The cellular system employs a central controller that uses advanced processing technology to keep track of all the channel assignments within the system to maintain the required channel isolation. However, hand-off now becomes a problem. In hand-off, a mobile user crosses from one cell where the current frequency is allowed into a cell where it is not. This requires the system to change the frequencies used for the communication link. If a channel is unavailable in an adjacent cell, the call fails abruptly at cell borders.

A related problem of current channel assignment schemes is the inability to have instant access to the communication system at any time. Channel assignments increase the time the central controller requires to establish a communication link and may even prevent calls from being established.

Cellular systems also suffer from multipath problems, especially near cell borders, where users receive desired signals both from a central transmitter and sources such as reflections from buildings. If the signals add out of phase then they may cancel and become severely degraded. This problem is also encountered in radio telephone and other current mobile systems.

A similar problem occurs for mobile users moving away from central transmitters at speeds that give rise to Doppler effects and phase shifts. Here the standing wave pattern from the transmitter appears to face every half wavelength creating continual reception problems. In addition, motion on the order of 70 mph can produce Doppler shifts on the order of +/- 80 Hz at frequencies of 800 MHz which can increase inter-channel interference.

The FM type cellular and radio telephone system broadcasts are not efficient techniques for transferring digital data signals. Current user demands call for data transmission links that are high quality exhibiting very low bit error rates on the order of  $10^{-6}$  or  $10^{-8}$  at data transfer rates on the order of 2400 to 4800 baud with future data transfer rates extending up to 19,200 baud.

Increasing capacity by using smaller cells is useful in large, high user density, metropolitan or urban regions but not in low user density rural regions. Increased capacity is not likely to be achieved economically (cost of base station versus number of users served in region) in rural areas. Therefore, while cellular telephone meets some of the demands of large metropolitan areas it does not meet the demands of rural areas which comprise 25 percent of the population and 84 percent of the land mass for countries like the United States. In addition, larger rural cells can decrease the frequency reuse in adjacent urban areas. This occurs because a single large cell is adjacent to several small cells which cannot use the same frequency. This and other design considerations and problems for cellular systems are discussed in further detail in IEEE COMMUNICATIONS MAGAZINE, Vol. 24, No. 2, February, 1986, especially pages 8-15 which are incorporated herein by reference.

It has previously been assumed that satellite systems are required to economically provide service to low density, rural or remote areas. However, satellite systems generally utilize high volume communication links to transfer otherwise terrestrially based telephone communications over single large distances between terrestrial relay stations for further transfer. This does not address the needs of mobile users or system users already without local telephone service.

Some satellite systems have been proposed to address single users through individual antennas instead of central relay stations, but the frequencies at which satellites operate and the methods of transmission have led to the use of rather large fixed antennas which are expensive and not amenable to use in mobile systems.

Proposed satellite services generally operate as FDMA systems employing UHF frequency repeaters and AM modulation schemes such as Amplitude Companded Single Sideband (ACSSB). Frequency reuse can be used for satellite systems similar to cellular systems discussed above. The continental U.S. can be divided into geographical regions or cells by using a multiple beam antenna where a separate beam is used for each region. If the signals in each region or antenna pattern experience an attenuation on the order of say 10 db with respect to those in the nearest neighbor region and 20 db with respect to the next adjacent regions and so forth, then a given frequency can be reused two regions away based on 20 db sensitivity rejection. This roughly doubles the number of users allowed at any time within a transcontinental communication system. However, this does not match demand for services.

Antenna designs have been proposed which would scan the antenna patterns across the target geographic regions using advanced frequency scanning techniques. These antenna schemes take advantage of the fact that different frequencies can be reflected at different angles by a given antenna reflector as used on communication satellites. This means that as the frequencies transmitted by the antenna radiator system change, the virtual spot created on the earth by the antenna reflector will move. In this manner the same antenna structure is made to alter the beam location. However, such techniques use the antenna structure to direct different frequencies to different regions, thus failing to fully take advantage of frequency reuse by allocating only a

portion of the total spectrum to each region.

Satellite systems do not use terrestrially based repeaters that communicate directly with users or a series of multiple satellites that communicate with the same user. Therefore, current systems do not provide universal service, that is, the ability for users to change position over a large geographical range and still be able to communicate without using alternate transmission equipment or new frequency bands. In multiple satellite systems frequency reuse would be limited by the isolation between geographic target regions. Satellite systems also experience multipath, blocking, and fading problems similar to mobile radio and telephone systems.

Alternate methods of decreasing user interference include time division multiple access (TDMA) or multiplexed (TDM) systems. Such systems use a central receiving station to multiplex or interleave separate user signals in time so that each signal only uses a portion of the total outgoing signal to the satellite. The time division approach divides the total spectrum up into predetermined temporal increments. All signals in the communication repeater system are allocated portions of this time controlled sequence. Therefore, no other user is using the link at the same exact time. The allocated portions are very small and the interleaving very large so that it appears simultaneous to all users. However, this time based synchronization of signals creates a natural limit to the number of users that can be coordinated "simultaneously" which is lower than desired. Also synchronizing a large number of simultaneous users greatly increases the complexity and cost of the system.

What is needed is a communication system that accommodates a larger number of users throughout a variety of user environments from high density urban to very low density rural. The communication system needs to exhibit increased capacity within standard spectral allocation bandwidths but with the same or better communication quality than presently available. In addition, a need also exists for a communication system capable of handling high speed low bit error rate digital data transfers at low power densities.

A system in which a satellite uses a ground implemented beam former is disclosed in National Telecommunication Conference Record '77, Vol. 2, December 1977, pages 19: 301 to 19: 3-7, I.E.E.E., New York, U.S.: "An S-band phased array for multiple access communications" by W.A. Imbriale et al. The beam former provides 20 simultaneous beams for a maximum of 20 simultaneous users only. The possibility of additional users is apparently not catered for. Users use different quasi-orthogonal codes to bandwidth-spread the information signals. Mutual interference between users using the same spectrum portion is reduced using the wellknown principle of processing gain.

Therefore, with the above disadvantages present in the art in mind, it is an object of the present invention to provide a multiple access communication system having high simultaneous user capacity.

According to a first aspect of the invention, there is provided a multiple access, spread-spectrum communication system, and comprising means for communicating information signals between at least two of a plurality of system users, using corresponding code-division-spread-spectrum communication signals, characterized by isolation means coupled to the means for communicating for unequally weighting signal power of the spread-spectrum communication signals. The isolation means can comprise a phased array antenna coupled to means for generating substantially simultaneous multiple steerable beams; and antenna structure configured to obtain either one or both of two circular polarization states; transceiver means for transmitting or receiving the same communication signals by two or more locations to create constructive interference maximized signal reception; first power control means for adjusting an output power duty cycle for said code-division-spread-spectrum communication signals in response to a predetermined activity level for said information signals; or second power control means for adjusting said output power level for said code-division-spread-spectrum communication signals in response to a minimum power level required to complete a communication link.

The preferred embodiment of the multiple access, spread spectrum communication system of the present invention further comprises means for transmitting a predetermined pilot chip sequence to users contiguous with said code-division-spread-spectrum communication signals.

In a preferred embodiment the means for communicating comprises chip generation means for generating a plurality of quasi-orthogonal spreading functions; code selection means for assigning one of the spreading functions to a user; and a plurality of mobile user terminals capable of transmitting or receiving code-division-spread-spectrum communication signals. Each of the user terminals uses a transmitter for generating a code-division-spread-spectrum communication signal according to an assigned spreading function in response to an input information signal; a receiver for detecting a code-division-spread-spectrum communication signal and generating an output information signal according to said assigned spreading function; and an omnidirectional antenna. At least one repeater is used for receiving communication signals from the plurality of user terminals and for translating the code-division-spread-spectrum communication signals to a form suitable for transfer to an intended recipient.

The repeater preferably employs means for transmitting a predetermined pilot chip sequence to users contiguous with a communication link and the receivers include a pilot sequence tracking loop. An activity detector

is included in the repeater for sensing signal activity levels in said information signals and decreasing repeater transmission power duty cycle in response to a decrease in sensed activity below a predetermined threshold level for predetermined sampling time.

5 The user terminals can also comprise an activity detection means for sensing signal activity levels in the input information signals decreasing user terminal transmission power duty cycle in response to a decrease in sensed activity below a predetermined threshold level.

10 The terminals can further comprise power control means for sensing a received power level present in received code-division-spread-spectrum communication signals and for adjusting the output level power applied to an antenna for transmitting code-division-spread-spectrum communication signals in response to the sensed power level.

The antenna of the preferred embodiment further comprises polarization control means for adjusting the antenna so as to select a predetermined polarization mode.

15 The repeater means can comprise at least one terrestrially based repeater or at least one satellite based repeater or both. The communication system preferably employs at least two satellites and earth based repeaters. Generally the satellite repeaters are interconnected to other communication systems using a central control station known as a hub. Users can access either type of repeater based on their location and assigned communication links. In this manner universal service is obtained in a manner previously unavailable and terrestrial repeaters in high user density regions can offload local users to decrease the power drain on satellites or increase their capacity. The repeaters preferably use a phased array antenna structure to create simultaneous multiple steerable beams.

20 In the preferred embodiment of the invention the communication system further comprises a demodulator, using a radio frequency mixer to correlate a local reference signal with input code-division-spread-spectrum communication signals. The resulting intermediate frequency spread spectrum signal is filtered to remove undesirable frequency components. A phase division means connected in series with the filter divides the spread spectrum signal into an analog in-phase signal and an analog quadrature signal which are then converted into digital in-phase and quadrature signals at a variable rate. Combiner means transfers the digital in-phase and quadrature signals onto a single data line in serial fashion for processing by other components within the demodulator.

25 A pilot chip reference means generates a local bit sequence corresponding to a predetermined pilot chip sequence transmitted contiguous with communication signals received by the demodulator. Carrier tracking means connected to the combiner and the pilot reference means compares the local pilot chip sequence to received signals in a timed relationship to determine the timing of the code-division-spread-spectrum communication signals with respect to the said local pilot chip sequence. A decision is then made to adjust the frequency of the local mixer frequency source. Chip synchronization means connected to the combiner and the pilot reference means compares the local pilot chip sequence to received signals in a plurality of timed relationships to determine the timing of code-division-spread-spectrum communication signals with respect to the local pilot chip sequence. The comparison determines if the rate for the analog-to-digital conversion needs adjusting.

30 A unit chip means generates a bit sequence corresponding to an assigned spreading function which is used by despreading means connected to the combiner for generating despread-spectrum in-phase and quadrature information signals. These signals are then combined in an output means to form an output information signal.

35 The above described preferred embodiment is a communication system having automatic Doppler shift and fade control, and the system is capable of expansion to meet future needs and interfacing with future alternative communication systems. The system includes an inexpensive system user terminal capable of meeting the needs of a variety of mobile or remote users, and transmission and receipt of high speed digital data signals is possible with very low bit error rates.

40 According to a second aspect of the invention, a method of providing high capacity multiple access communications to a plurality of communication service users is characterised by the steps of converting a plurality of narrow band input information signals into a plurality of wide band user addressable code-division-spread-spectrum communication signals, using an assigned spreading function, and a predetermined carrier frequency; communicating the code-division-spread-spectrum communication signals between users; weighting signal power unequally in communication of the spread-spectrum communication signals, with signals directed to an intended recipient user of greater average signal strength with respect to interfering signals directed to other users; and converting each received address corresponding code-division-spread-spectrum communication signal to a corresponding narrow band information signal.

55 The invention also includes a spread-spectrum multiple access communication system having high system user capacity, comprising means for communicating system user addressable information signals between at least two of a plurality of system users using address corresponding code-division-spread-spectrum commu-

5 nication signals, the means for communicating generating mutual interference in communications between the said at least two system user by contemporaneously communicating code-division-spread-spectrum communication signals between other system users, and the means for communicating having a processing gain for reducing the mutual interference; characterised by isolation means, coupled to the means for communicating, for providing an increase in system user realized average signal power for the system user address corresponding code-division-spread-spectrum communication signals in communications between the said at least two system users relative to mutual interference signal power of the contemporaneous communications between the other system users.

10 According to another aspect of the invention, there is provided a method for providing high system user capacity in a spread-spectrum multiple access communication system in which system users communicate user addressable information signals using address corresponding code-division-spread-spectrum communication signals in which, with respect to communications between at least two system users, other system users generate mutual interference by contemporaneously communicating code-division-spread-spectrum communication signals with the said system having a processing gain for reducing mutual interference, the method  
15 further reducing mutual interference in communications between the said at least two system users and being characterised by the steps of: providing a plurality of system user addressable narrow band information signals; converting the plurality of system user addressable narrow band information signals into a corresponding plurality of system user address corresponding wide band code-division-spread-spectrum communication signals; transmitting the plurality of code-division-spread-spectrum communication signals between system users; receiving, at each respective system user, system user address corresponding code-division-spread-spectrum communication signals and other respective system user addressed code-division-spread-spectrum communication signals as mutual interference; providing for each representative system user an increase in system user realized average signal power for the system user address corresponding code-division-spread-spectrum communication signals with respect to mutual interference signals power of the other system user address corresponding code-division-spread-spectrum communication signals; and converting, at each respective address user, received address corresponding code-division-spread-spectrum communication signals into corresponding user addressable information signals.

20 The method of the present invention may also comprise the steps of transmitting a pilot chip sequence and transmitting and receiving signals through repeaters. The repeaters can include at least one terrestrial and/or at least one satellite based repeater.

30 The invention will now be described by way of example with reference to the accompanying drawings in which like characters refer to like parts and in which:

FIG 1a is a plot of antenna gain versus angular deviation from boresight center for an exemplary antenna used in a satellite communication system;

35 FIG. 1b is a table of actual and "weighted" users versus antenna gain and angular deviation for the antenna of FIG. 1a when used in the communication system of the present invention;

FIG. 1 is an overview of a communication system constructed according to the principles of the present invention;

FIG. 3 is a schematic of a repeater employed in the system of FIG. 1 using an omni-directional antenna;

40 FIG. 4 is a graphic plot of average user power to establish a communication link versus the distance from a terrestrial repeater;

FIG. 5 is a schematic of another repeater employed in the system of FIG. 2 using a phased array antenna structure;

FIG. 6 is a graphic plot of average user power versus the distance from a repeater;

45 FIG. 7 is a schematic of an orbital repeater and a communication system hub used in the system of FIG. 2;

FIG. 8 is a plot of relative signal strength versus position for a satellite interference pattern;

FIG. 9 is a schematic view of a hub interferometer communication link;

FIG. 10 is a schematic of the user terminal employed in the system of FIG. 2;

50 FIG. 11 is a view of an antenna for use in the system of FIG. 2;

FIG. 12 is an illustration of elliptical ratio;

FIG. 13 is a graphic presentation of capacity versus antenna ellipticity;

FIG. 14 is a tabular listing of capacity versus ellipticity and axial ratio;

FIG. 15 is a schematic of a demodulator used in the user terminal of FIG. 10; and

55 FIG. 16 is a schematic of a modulator used in the user terminal of the FIG. 10.

The present invention comprises a new communication system employing one or more satellite or terrestrially based repeater stations to provide communication links among a large number of mobile or fixed, and local or remote users. To obtain a large number of users, the user terminals within the communication system

employ new modulators and demodulators to transmit forward-error-correcting-coded communication signals using Code Division Multiple Access (CDMA) spread spectrum transmission signals. In addition, system capacity and communication is further enhanced by using means for providing marginal isolation between users comprising multiple beam phased array repeater antennas, polarization enhanced mobile antennas, means  
 5 for generating Interference patterns for reception and transmission of communication signals, voice or data activity switching, or adjustable user terminal power control. Additionally, independent pilot chip sequence signals are used to improve acquisition and tracking.

Traditionally, CDMA has been held to be inferior as a multiple access technique in comparison to FDMA and TDMA because it appeared to provide inferior spectral utilization. This was based on the argument that  
 10 for TDMA or FDMA, the number of equal bandwidth channels that a given band can be divided into is approximately equal to the total bandwidth divided by the bandwidth per user channel. Whereas, CDMA provides fewer channels according to the following argument.

In a bandwidth limited environment where a number of equal users desire to share a common frequency band using CDMA, the number of such equal users is determined by the following formula:

$$I/S = W/R - E_b/N_0 \quad (1)$$

where

I is the total interference power seen by each user's receiver and is equal to the total power of all the users, which is equal to the number of users times the power per user;

S is the power of one user's signal, thus I/S equals the effective number of users;

20 W is the bandwidth occupied by the spread spectrum signals;

R is the data rate of each user; and

$E_b/N_0$  is the signal-to-noise ratio required for the modulation and coding system employed.

Since it can be seen that W/R is the TDMA and FDMA capacity, the CDMA capacity would seem to be always less by an amount equal to  $E_b/N_0$ , for practical systems, approximately 3 - 5 dB, depending on the particulars  
 25 of the modulation and coding system employed.

The present invention greatly increases the capacity of CDMA systems by employing means for producing marginal isolation. The term, marginal isolation, will be defined herein. The key idea is that the spread spectrum receiver sees the weighted sum of all the users' incident power as interference to the one desired signal. If the system includes means to provide non-uniform weighting, then increases in capacity can be obtained from  
 30 differences in weighting. Differences too small to be of use to FDMA or TDMA systems are quite valuable to a CDMA system.

In previously proposed CDMA satellite systems, a wide band transponder with earth coverage antenna has been employed. Such an antenna provides nearly the same gain to all users, no marginal isolation is realized and performance is, in fact, worse for CDMA than for TDMA or FDMA. The present invention, however,  
 35 utilizes a multiple steerable beam antenna which provides the capability to realize marginal isolation. Such an antenna also increases the capacity of FDMA and TDMA systems, but provides far more capacity gain for CDMA. This is because FDMA and TDMA systems require at least 15 dB isolation of co-channel signals in order to provide acceptable performance, while the CDMA system obtains useful capacity increases from isolation as small as 1 dB.

Marginal isolation is defined as a system characteristic that provides unequal weighting of the incident received power of interfering user signals. Embodiments of the present invention utilize several mechanisms for providing marginal isolation, including multiple steerable beam antennas, antenna polarization, formation of interference beam patterns from multiple satellites, path loss differentials for interferers at different distances, and less than continuous transmit duty cycle. Additional methods of producing marginal isolation may be devised by those skilled in the art of communications system design.  
 45

An exemplary communication system 30 would use a spread spectrum bandwidth, W, of 8 MHz and an information signal bandwidth, R, of 5 kHz for a bandwidth ratio of 1600 and a processing gain of 32 dB. If we assume  $E_b/N_0$  to be 5 dB, the number of users can be computed from equation 1. Under these conditions I/S is 27 dB. The total number of users (I + S) is, therefore, approximately 500. This means that the communication  
 50 system supports 500 users under these conditions. But these are users all operating under the same conditions and with equal power and isolation within the system.

If instead the system users are isolated or contribute unequally to the interference in the system communication link, new users can be added. This can be illustrated using an antenna pattern that exhibits a relatively flat "response" or gain across the middle of a beam width and then falls off sharply on the edges. If we assume  
 55 an equal distribution of users over an area larger than the central high gain portion of the antenna beamwidth, then each user is "weighted" by the relative gain effected for its signal because of a roll-off in gain. FIG. 1, shows the impact of this roll-off for a communication system.

FIG. 1a shows a plot of the actual, maximum, and minimum gains versus single-sided angle from boresight



of a typical satellite antenna used for L-Band transmission from synchronous orbit. This antenna pattern represents an antenna optimized for an FDMA system, not a CDMA system. FIG. 1b shows the minimum and maximum gain data in a tabular form with gain regions and angles expressed as double-sided or total angle from the center of the boresight. If we use the maximum gain in each region and the gain factor for the entire region and assume that there is a uniform distribution of users across the typical 7.4° width of the United States, then FIG. 1b shows how a total population of 2326 users has the same effective interference as 500 users having the strength of the user of interest.

The "Δ Angle" column gives the angle size of each gain range. The "# of Users" column is calculated by multiplying the total number of users by the fraction of users at this gain. The following equation is used:

$$\# \text{ of Users} = \frac{\Delta \text{ Angle}}{\text{Total Angle of US}} \text{ Total Users} \quad (2)$$

The "Weighted # of Users" column is calculated by multiplying the "# of Users" column by the maximum gain of that range. This calculates the equivalent number of users at 0 dB that would produce the same interference as the users in this region at this maximum gain. The following equation is used:

$$\text{Weighted \# of Users} = \# \text{ of Users} \cdot 10^{-(\text{MaxGain}/10)} \quad (3)$$

It is important to note how even attenuations of as small as 1 dB reduce the weighted total. Lastly, the "Weighted # of Users" is totaled. The number of users in the U. S. was adjusted for purposes of illustration so that the "Weighted Total" was approximately 500 users as used above.

The "CDMA Reuse Factor" of 4.65 was calculated as the ratio of 2326:500. The "FDMA Reuse Factor" of 3.70 was calculated as  $7.4^\circ / (1.0^\circ \cdot 2)$ . 7.4° is the width of the U.S., 1.0° is the 2 dB beamwidth of the antenna, and one needs to use one half of the frequencies in one beam and then the other half in the next beam; so it takes two beamwidths before the frequencies. Using the antenna optimized for FDMA, CDMA shows a better reuse factor. If the same size antenna is optimized for CDMA -- minimum noise beamwidth -- then the CDMA reuse factor can be further increased to 6.67 giving a reuse gain of  $6.67/3.70 = 1.80$ .

As can be seen, the total number of "effective" users is 500 while the system is actually supporting 2326 users if multiple beam positions are provided so that all users can be received near the center of a beam. Therefore, the system used marginal isolation of a few dB, which is useless to other systems, to provide frequency reuse. This ability to increase the effective adjacent user attenuation allows the present communication system to provide greatly increased frequency reuse as compared to other communication systems.

An overall schematic of a communication system operating according to the principles of the present invention is illustrated in FIG. 2. In FIG. 2, a spread spectrum communication system 10 employs terrestrial repeaters 12 or orbital repeaters 14 with one or more central stations 16, to transmit and receive information to or from mobile terminals 20 or 22, and fixed terminals 24 or 26.

The term information is used to encompass both digital data and voice since some terminals will transmit, or be equipped to transmit, signals in the form of digital data as well as the typical analog or voice signals. Transmission of digital data is generally accomplished using an appropriate interface for linking a data generation source 28, such as a TTY device or computer, with the user terminal 22 or 26 circuitry. Modems and other data communication interface devices are readily designed and understood by those skilled in the art and are not described in detail here.

The preferred embodiment of the communication system 10 makes extensive use of the mobile terminals 20 or 22 since the fixed terminals 24 or 26 provide less of an advantage in large urban areas where high quality "wire borne" communication links are easily and cheaply accessed. However, fixed terminals 24 and 26 located in distant or remote locations will gain great advantages from the communication system 10 since terrestrial wire or cable based links are prohibitively expensive, difficult to install, or even non-existent in many areas.

The communication system 10 uses, or evolves in stages to use, several alternative paths for communication. An initial communication system 10 installation would perhaps use exclusively terrestrial based repeaters 12 which communicate with and relay information between the terminals 20, 22, or 24. This is illustrated by the portion of system 10 to the right of the double dashed line dividing the system 10 into two parts, a terrestrial portion and a satellite portion. The earth based repeater 12 of the present invention advances the communication art by providing improved high quality, high capacity communications. However, the terrestrial portion of the communication system 10 is also constructed to interface with an orbital satellite repeater 14.

The initial system accommodates many remote or mobile users with communication links 30 through terrestrial repeaters 12 that are interlinked by existing telephone networks 32, or through dedicated fiber optic or radio communication links 34. Then when a satellite is launched, the communication system 10 uses satellite links 36 to interconnect users, especially rural users. Later on additional satellite repeaters 14 are launched to provide improved communications and higher system capacity. Additional control and signal processing is preferably provided in the satellite portion by using central ground stations or hubs 16 via satellite links 38.

This makes the communication system 10 highly flexible and advantageous for handling a variety of com-



munication needs and services. The communication system 10 accommodates a larger user base or geographical service area commensurate with governmental agency approval and satellite development and launch timing.

5 This dual system has additional advantages over current systems, both in terms of universal service and interference. Universal service allows users to move freely throughout the system and have communications regardless of location. That is, mobile access is provided to users that switch between rural, suburban, or urban areas, and land, aeronautical, or water based forms of travel. This service is provided on individual, low cost user terminals without equipment alteration. This also means that users have communication system 10 access even when out of normal "home coverage" area provided by a cellular arrangement.

10 The communication system 10 can be configured as a cellular system using varied cell sizes with larger cells positioned adjacent to many smaller cells. While this decreases the amount of frequency reuse, it will not be a substantial limitation for the communication system 10 due to its greatly increased frequency reuse capabilities. It can accommodate such a limitation or loss of reuse and still serve more users than previous communication systems. The communication system 10 does not require the same guard cells or spaces for frequency reuse as previously seen in cellular systems.

15 As previously discussed, current communication systems such as cellular telephone, or mobile radio, are SCPC or single channel per carrier FDMA systems that divide the overall spectrum into discrete channels or frequencies for each user or communication link. These communication systems employ AM or FM modulation techniques that generally require minimum attenuation between users on the order of 15dB for FM to 30 dB or more for AM.

20 The communication system 10 uses spread spectrum signal transmission techniques to increase user capacity by establishing coded digital communication signals that use quasi-orthogonal bit sequences to decrease mutual interference. At the same time, the communication channels are spread across or occupy the entire allocation bandwidth, which improves communication quality, allows for increased bandwidth signals and decreases the effects of frequency selective fading.

25 Spread spectrum communication involves processing the outgoing information signal with a spreading function which changes or expands a narrow bandwidth signal into a broad bandwidth signal. The spreading function is a reproducible function which spreads the narrow bandwidth transmission signal over a broader bandwidth and reduces the peak spectral density of the signal. This is direct sequence spread spectrum coding. Alternatively, the carrier frequency can be pseudo-randomly hopped over the spread bandwidth. Direct sequence spread spectrum is preferred for applications addressing multipath impairments.

30 In the communication system 10, this is accomplished by converting analog input information signals, such as voice, into digital form and multiplying them by a high bandwidth high frequency digital spreading signal. Digital input signals can be directly spread. The resulting spread spectrum signal is then used to modulate a carrier and create a communication signal. It is also possible to modulate the carrier first and then apply the spreading function but for the preferred embodiment the first approach is used for ease in digital processing.

35 The high bandwidth spreading signal comprises a deterministic series of bits of period  $T_c$  referred to in the art as chips. The chips or chip sequences are generated using electronic apparatus and techniques known to those skilled in the art. There are a variety of techniques as well as known coding formulas for generating spread spectrum chip sequences. Exemplary techniques or methods are described in further detail in SPREAD SPECTRUM COMMUNICATIONS, Volume 1 by M. K. Simon et al, Chapter 5, pages 262-358 which is incorporated herein by reference.

40 The chips are generated at a much higher frequency than the input voice or data signal. By generating the chips at this higher frequency, a series of chips are generated for every single information bit. The specific chip frequency used depends on the allocation bandwidth for the communication system 10. It is desirable to spread the communication signal to cover the entire allocation bandwidth where possible and achieve a high processing gain, as discussed below. Also, the higher the chip rate the more users a spread spectrum communication system can service since higher rates generated more chips per information bit and more quasi-orthogonal codes with which to differentiate between users.

50 For a spectral allocation bandwidth of 9 MHz and using a fifth order elliptical filter to process the spreading signal, a chip frequency of approximately 8 MHz would be used to provide a signal having a 2 dB pass band ripple and 30 dB stop band attenuation. This frequency provides long chip sequences, which provides a large number of discrete addresses or codes for differentiating between users.

55 The communication system 10 uses Code Division Multiple Access (CDMA) signals to increase the user capacity of the system. This is done by assigning each user a specific code in the chip sequences so that the cross-correlation function between users is small and the users are said to be quasi-orthogonal to each other. As previously stated, there are known coding functions which can be used to determine or generate a family of codes or chip sequences. An exemplary set would be the GOLD codes which are also discussed in the pre-

viously mentioned SPREAD SPECTRUM COMMUNICATIONS reference.

The chip sequences can be generated or chosen so that a predetermined or unique chip sequence is assigned to a specific user for the entire time a user terminal is used in the communication system 10 or assigned each time the user starts a communication link as part of the call setup protocol. This, of course, means maintaining a central log or listing of all user sequence assignments.

The earth based or terrestrial repeater 12 or the communication system 10 is illustrated schematically in FIG. 3. In FIG. 3, the repeater 12, which can be located in a rural or urban region, employs an antenna 40 to receive or transmit communication signals. The antenna 40 is coupled to a duplexer 42 which allows coupling the antenna to both the transmit and receive sections or modes of the repeater 12. This simplifies the antenna design and installation by using a single antenna structure as opposed to two. However, it is not necessary for the function of the present invention to use a single antenna.

The duplexer 42 transfers incoming or received communication signals through a receive power splitter 44 to spread spectrum receivers 46, each of which will handle a specific user or communication link. Therefore, each repeater will employ as many spread spectrum receivers as users or communication links it is expected to accommodate at a given time. The receivers 46 contain circuitry to change the incoming communication signals to a lower IF frequency and track and lock onto the signal. The receivers 46 then remove the carrier and despread the signals to provide a digitally encoded signal. The encoded signal is then transferred to data-to-voice decoders 48 where they are changed to analog or voice signals for use over a terrestrially based link. In FIG. 3 a telephone network interface 50 is used to couple the voice signals to telephone lines for transfer to other locations. In the alternative, a fiber optic coupler, not shown, could be used to couple signals into a fiber optic communication cable. The interface and fiber optic couplers represent devices that are commercially available and designed by those skilled in the art of terrestrial communication systems.

The repeater 12 may also communicate incoming signals directly with other mobile users within the region it is servicing. In this case, a repeater controller 52, which can comprise microprocessor controllers and circuitry, routes the decoded communication signals to the user that is specified in the communication protocol (chip sequence assignment). Both users for this communication link are assigned specific receivers and transmitters. Previously each user was assigned a specific channel. The term channel can still be used for the communication system 10 but it now refers to a percentage of the overall power of the system. Every user generally occupies the whole spectrum used by the repeater but is allocated only a portion of the power available to the repeater, determined by the minimum amount of power required to establish and maintain a communication link. In the preferred embodiment the overall spectral allocation is divided in half with one half used for the uplink portion and the other for the downlink portion of communication links.

By using this type of power control the amount of power required for maintaining communications with users decreases as the users are closer to the repeater based on the attenuation of radio waves over distance. The effect of the power decrease is illustrated in FIG. 4 where a plot of average power used to make a communication link versus distance from the repeater is shown. It can be further shown that for this type of distribution the total power required for the repeater is decreased almost by a factor of 2. This decrease can be used to reduce the power requirements for the repeater or to increase the capacity by a factor of 2 for the same power requirements. This reduction of power also reduces interference in neighbouring calls.

Returning to FIG. 3, information signals, either from the terrestrial link or another "local" user, are transferred back through voice to data encoders 54 to transmitters 56. In the transmitters 56 the digitally coded signals are spread and used to modulate a carrier to form the desired communication signal. The communication signal is now transferred through the transmitter power combiner 58 and duplexer 42 to antenna 40.

For communication signals remaining within the region serviced by the repeater 12, the preferred system of the present invention would not route intermediate versions of the signals through the digital decoders 48 and encoders 54. Instead the signals are transferred directly between the receivers 46 and transmitters 56 only providing so much of the decoding as necessary to change the spread spectrum code assignment rather than actual conversion to analog form.

The repeater of the present invention can transfer a single communication signal to as many users as desired without requiring duplication of the signal. In this regard the protocol used for the sending of messages can accommodate an indication of multiple users in the address. Therefore, for some services one message can be detected by the receivers 46 and quickly transferred directly to several transmitters 56 for reception by several users. This is the so called one to many form of transfer useful for some types of dispatch and data transfers. The repeater can also easily accommodate the reverse, where several communication signals are transferred to a single receiver. The many to one type of transfer.

Another advance over the art for the repeater 12 is the inclusion of a voice activity detector in the circuitry. This detector monitors the activity of signals processed by the circuit to decrease the power utilized in the absence of communication. In a CDMA communication system it is possible to employ fast attack, threshold sen-

sitive, detectors that can decrease the signal level, energy, or transmitter power used during periods as brief as between syllables in conversation. FDMA and TDMA communication systems cannot reassign channels or take similar steps in this short a time period. For pauses during digital data transmission this is equally applicable. The power reduction is accomplished by gating off the transmitter except for brief, periodic bursts to maintain synchronization. This can be accomplished by generating a control signal which alters the duty cycle of power output circuitry.

The activity detection and power control results in a net savings of energy usage for the communication system 10. It is estimated that as much as 40 percent of the total time consumed by a typical conversation can be treated as "dead" time. The bit error rate and signal quality for each user is determined by  $E_b/I_0$  on an instantaneous basis. Therefore, if some of the interference is gated off then  $I_0$  decreases and the remaining user interference also decreases which in turn increases system capacity. The resulting reduction in average power per user is also important for the orbital repeaters 14 which operate in a power limited environment.

The elimination of about 40 percent of the "conversational" dead time in the communication system 10 increases the system capacity by as much as 2 1/2 times. This increase in system capacity or number of communication channels is not possible with FDMA and TDMA communication systems because of the difficulty in switching busy or active channels into idle channels during conversational pauses. In addition, the inherent time delay imposed by signal transmit times, makes coordination of such signal switching for use in the uplink portion of a communication link impossible in satellite FDMA or TDMA systems.

Additional advantages are realized if an antenna array is used for the repeater 12. The antenna array of the preferred embodiment forms multiple steerable beams that are directed to specific users which increases the isolation between users. This is shown schematically in FIG. 5 where a phased array repeater 60 uses the intrinsic properties of a phased array to create beam directionality and also multiple beams which can be directed to specific users or user regions. The modems 64 comprise the circuitry previously shown in FIG. 3 above, with the exception of the antenna 40. The antenna now employs a different structure and some new control elements.

Signals that were previously transferred to a single antenna 40 are now transferred to a beam former 62. The number of beam formers 62 used in the repeater 60 depends upon the amount of control desired over the communications to individual users versus the cost and complexity that can be accommodated. The more beam formers used, the greater amount of control that can be exercised over each communication link from the modems. The maximum number of beam formers used would correspond to the number of modems and provide optimal control over user communications. However, this is overly complex for most communication uses.

Each beam former transfers signals from its associated transmitters in the modems 64 to a series of antenna elements 66 comprising a phased array 68. As will be apparent to those skilled in the art, the phased array antenna functions by controlling the relative phase of the signals transmitted by the individual elements 66 to form a beam along a specific direction. By controlling the relative phase of the transmission of signals from the elements 66, the transmissions are summed in space to form a single beam traveling along a particular direction. Controlling the phase of the elements controls the resulting beam direction.

Each beam former 62 is designed to transmit signals along a specific beam pattern or patterns. The beam formers 62 accept signals from the modems 64 and create as many duplicate or parallel signals from each single communication signal as there are antenna elements 66. In FIG. 7 three elements are shown for purposes of illustration only. The preferred embodiment of the communication system 10 uses from 6 to 15 elements in a two dimensional array or pattern, but is not limited to these numbers. The number used depends upon the amount of frequency reuse that is desired, realistic attenuation limitation, and the allowable complexity of the repeater 60.

The beam formers 62 then alter the phase of the parallel signals using techniques known in the electronics arts and transfer these signals to the antenna elements 66. At the same time, the outputs from each of the beam formers 62 is summed by digital combiners 70. This is done so that all of the power intended for each element is summed and transferred to that element and the transfer is isolated from returning through adjacent beam formers. This allows for multiple beams to be formed and directed by the array simultaneously by the beam formers 62.

It is further possible to permanently assign receivers and transmitters to the beam formers so that they function to handle communications within preselected regions or along dedicated communication links. While dedicated communication links tend to decrease the capacity of the communication system 10, there are priority users such as emergency services that often require or demand this kind of service.

The phased array of the repeater 60 is also equally useful for scanning a region or directing a receiving pattern to detect specific regions or users. The scan pattern for the array can be predetermined by the assignment of receivers to monitor specific regions or directions. However, the array of the present invention is not limited to static assignments. An antenna controller 72 provides signals to the beam formers 62 which alters

the directional assignment used by each beam former. In this manner new steerable beams can be created or additional beams directed into regions where increased user capacity is needed. Also, incoming signals can be detected in terms of the phase relationship required for the highest strength. The phase of the array can be periodically scanned or slightly adjusted to provide this information. Then the same phase relationship can be used in the array for the return signals to that user. In this manner not only can improved communication be obtained over the reception link but also for the transmission link.

The communication system 10, as previously discussed in relationship to the illustration of FIG. 2, can employ a series of terrestrial and satellite repeaters to form a large interlinked communication system. As shown in FIG. 1, repeaters 12 can be subdivided into the repeaters 12a and 12b as well as the satellites 14a and 14b.

The terrestrial based repeaters 12a serve high user density urban or metropolitan areas while the terrestrial based repeaters 12b serve larger but lower density urban or sub-urban regions. The orbital repeaters or satellites 14a and 14b serve even larger geographical regions which are rural and low user density. While this is a preferred allocation of resources for the present invention, it is not the only possible allocation. For example, the orbital repeaters 14a or 14b can be used to service metropolitan areas where it is economically unreasonable to establish central base stations. This may also prove advantageous where it is desirable to have direct communication links between certain metropolitan users and rural users without any intermediary communication service links.

Another important feature of the communication system 10 is ability of the terrestrial repeaters, especially in the high user density metropolitan areas to "offload" local users from the satellite repeaters. That is, as users come within range of terrestrial repeaters they are linked through those repeaters preferentially. Note that the communication system 10 allows this to be a preferential transfer. If desired the user can continue to use the orbital repeater even though the terrestrial repeater is close by. This allows for improved communications where there is severe signal degradation due to fading, multipath, or direct blockage from the nearby terrestrial repeater.

The switch over to a terrestrial repeater now means that as the user moves closer to a repeater, less power is required for the communication link due to the simple power versus distance relationship previously discussed. This is illustrated in FIG. 6, where a plot of power requirements for a user link versus distance from a repeater is shown. In addition, an assumed user density is also plotted to provide an idea of the amount of power savings for the system. The fact that less power is required for the communication link also means that less power is being radiated in the system to create interference for other users. This synergistic relationship between the repeaters and the user access improves power considerations as well as capacity for the overall system 10.

The communication system 10 is very flexible and the orbital repeater assignments as to regions served can be altered to match current market demands for services. This is another advance provided by the present invention.

The satellite or orbital repeaters 14 of FIG. 2 can be configured in two different modes of operation. The first mode is the direct user link mode in which the satellite receives and transmits directly with users. The second mode is the central hub mode in which communications to and from users are routed through a terrestrially based hub.

In the direct user mode the satellite will employ a circuit similar to that shown for the terrestrial repeater in FIG. 5. The differences being the specific types of antennas and the fact that communication signals are not interfaced directly to a terrestrial service such as a telephone system. If the satellite employs the circuitry of FIG. 5, advanced VLSI and hybrid circuit techniques would be used to reduce the size and power consumption of the circuits.

While the orbital repeaters 14 can use the same basic circuitry as used in the terrestrial repeater, it is very desirable to employ as few circuits as possible in a satellite. It is desirable to have the satellite as much a passive relay as possible and use as little power as possible. Therefore, the preferable embodiment for the repeaters 14 utilizes a hub or control center 16 through which the communications will be passed and processed. This allows decreased power consumption in the satellite and greater system reliability by maintaining the banks of receivers and transmitters needed for the individual communication links on the ground.

This is shown schematically in greater detail in FIG. 7. In FIG. 7, hub 16 uses the same basic arrangement of transmitters and receivers as seen in the repeater 60 as illustrated in FIG. 5. Spread spectrum receivers and transmitters as previously described, are shown as Spread Spectrum (SS) modem banks 74 because of the manner in which they are grouped together as shown FIG. 5. Each bank of modems is connected on one hand to an interface 50 for a terrestrial communication link such as a telephone system or an optical fiber cable. Not illustrated in FIG. 7 are the voice and data encoders and decoders that would be used in association with the modes of the modem banks 74.

The modem banks 74 are connected to beam formers 76 which serve to generate the signals necessary

to form directed or steerable multiple beams as seen in FIG. 5. However, the output of the beam formers 76 are connected to an array of frequency unconverters 78 rather than power combiners or antenna elements. In essence, each satellite antenna element is provided with its own channel between the hub beam former and the antenna array. When polarization reuse is employed, the horizontal and vertical array elements are provided with separate channels to the beam former so that both right and left handed circularly polarized beams can be formed.

The signals provided by the upconverters 78 are communicated through a Ku band antenna 80 to an associated Ku band antenna 82 residing on an orbital repeater 14. This Ku band link between the satellite 14 and the hub 16 has several advantages over an L band link. The Ku band frequencies which are on the order of 14GHz, do not interfere with the spectral allocations of the rest of the communication system 10. This helps maintain system capacity by not consuming a portion of the power requirements for the system in these links. Another advantage of the present Ku band link is that the upconverters employ FM modulation techniques. This allows improved phase control over the signals as they traverse the long distance to a satellite and decreases the necessary control, signal processing, and complexity required in the orbital repeater to maintain high quality multiple in-phase communication links.

However, single sideband AM modulation is easier to implement where there are two or more hubs 16 which share the resources of the satellites. When two hubs communicate with the satellites at the same time, AM signals are easier to coordinate in the system.

In the orbital repeater 14 the received Ku band signals are detected and downconverted by Ku band transceivers 84. The signals are then transferred to L band transmitters 86 where they are amplified to controlled power levels and sent through duplexers 90 to the antenna elements 92.

As in the case of the earth based repeater 12, the antenna elements 92 form a two dimensional phased array 94 which provides multiple steerable beams for the communication system 10. It will be apparent to those skilled in the art that direct radiation of the earth by an array of 12 to 15 elements, as preferred, from geosynchronous orbit is impractical. The solution is to use a reflector 96 to create the desired pattern of focused beams at the planet surface.

It is possible to use a single antenna or even multiple antennas on the orbital repeater 14 and have a functional repeater. However, the preferred antenna structure provides many advantages over previous communication system designs in terms of capacity, regional control, special users services, etc., as discussed above. The multiple steerable beams formed by the array 94 can be directed to specific regions, or classes of users. As in the case of the terrestrial repeater, the direction of the steerable beams can be controlled by the hub 16 to reassign satellite coverage to new regions (size or location).

Communication signals traveling to the orbital repeater 14 from users will be detected by the array 94 provided they are in proper phase relationship to the tuning of the array. Received signals will be transferred through the duplexer 90 to the L band receivers 88. The signal is transferred to the Ku band transceiver 84 where it is upconverted and sent to the hub 16. Each of the receivers 88 is configured to receive the full bandwidth of the spectrum allocated to the communication system 10. However, for specific applications some receivers 88 could be limited to specific portion of the band to provide limited coverage of select regions or to accept or reject special dedicated services.

The hub 16 also employs the voice activity circuits previously described in order to decrease the power consumed by "empty" communication signals and increase capacity. Clearly this also decreases the power needlessly consumed by an orbital repeater, helping to increase the effective use of satellite power. The system capacity is increased due to the effects previously discussed with respect to activity detection and power control in the terrestrial repeater 12.

Another feature of the hub 16 is that it allows the communication system 10 to use multiple satellites or orbital repeaters 14 in a new advantageous configuration to achieve improved communication and orbital reuse. In addition, this is accomplished without increasing the complexity of the user terminal or requiring alternate types of terminals.

In conventional reuse, the hub 16 directs the satellites 14a and 14b to cover differing geographical regions by directing multiple steerable beams to specific locations simultaneously. In this manner the satellites are "reused" in that they can accommodate the same frequencies without concern for interference because of the isolation provided by the antenna structures.

Orbital reuse is provided in the communication system 10 even though the user terminals employ omnidirectional antennas. Unlike previous systems, fixed directional antennas are not required because the system 10 uses two or more satellites in a new coincident transmission configuration that can be thought of as a very large scale interferometer. This is made possible by the marginal isolation provided by the two satellites in conjunction with spread-spectrum modulation.

In this operational mode the satellites each transmit an appropriate communication signal to the earth, both

intended for the same user. The radio waves have relative phase variations due to path differences between the two satellites and the user. The two beams will form an interference pattern across the geographical target area with higher power densities where the beams constructively add and lower densities where they destructively add. This effect is illustrated graphically in FIG. 8 using a normalized value of 1 for the constructive addition of two satellite communication links. If a user is located in an in-phase, higher power density portion then the signal perceived by the user is effectively 3 dB higher than the other user interference which, on the average, receives no gain at the receivers location. This improved signal to interference ratio gain adds additional isolation margin to the communication system 10 and in turn increases the overall capacity.

For purposes of clarity in illustration the technique of the present invention is illustrated and discussed utilizing two satellites operating in this mode. However, additional satellites can be employed to achieve additional gain, such as 4.8 dB for three satellites, 6 dB for four, and so forth.

To place a user in the higher density portion of the interference pattern, two independent antenna beams are directed toward the user. Users can be "tuned" into the higher density portions of the antenna interference patterns by adjusting the phase and time delay of their signals. This same technique can be used for the uplink side of communication as well as the downlink. Path diversity also provides additional advantages in terms of countering multipath and fading effects.

The hub 16 circuitry for accomplishing the above operational mode is illustrated in FIG. 9. In FIG. 9 a modem or transmitter 100 provides a communication signal to two beam formers 102 and 104 at the same time. However, the delay devices 106 and 108 are disposed in the transmission links for the beam formers 102 and 104, respectively. The beam formers operate as previously described. Only two beam formers are shown for illustration, it being understood that the hub 16 may employ a larger number of beam formers as previously discussed.

One of the delay devices can provide a fixed delay while the other provides a variable length delay, since the relative delay is what is important. Alternatively, both delay devices 106, 108 can provide variable delay. The delay devices 106, 108 establish the relative time delay between the transmitted satellite signals. A phase adjuster 110 is also disposed in the communication link, here for beam former 104, to adjust the relative phase.

The signals from the beam formers 102, 104 are transmitted, as before, through frequency converters to the satellites. The signals from each beam former 102 or 104 are transmitted to different satellites where they are directed to a user, resulting in the desired interference pattern.

For the uplink communication signals from the respective system 10 users, the beam formers 112 and 114 act as receiving elements for the separate demodulators or receivers 116 and 118. Incoming communication signals are transferred to the demodulators where they are despread into digital communication signals. In order to coherently combine the resulting signals a coherent combiner 120 is coupled to the output of the demodulators 116 and 118. Delay devices 122 and 124 are positioned between the combiner 120 and the demodulators 116 and 118 to adjust the relative phase and timing of the signals into coherence. Once the signals are coherently combined into a single digital communication signal, the information is transferred to appropriate decoding circuitry for further processing.

The control over the phase and time delay for a given user depends on the quality or strength of the signals received by the hub 16. This information is derived from the demodulators 116, 118 and provided to the variable delay devices 106, 122, 124, and the phase controller 110.

The hub 16 is capable of monitoring communication from both satellites simultaneously. In this case, each communication link between the user and a satellite is treated as a separate link which is assigned separate receivers, decoders, etc. The hub 16 determines the relative phase and time delay difference between the two signals. This information provides signals to delay and rotate the separately detected and decoded signals into coherence or phase with respect to each other and coherently summed to produce a single output. This process provides approximately an additional 3 dB of gain. Interference from other users' signals adds incoherently producing 0 dB gain on the average.

Alternatively, the hub 16 utilizes the user assignment protocol in the communication links to determine that more than one link is in use. Then the hub compares the relative power or quality of each link. The link that provides the best error free, high power signal is retained and the other communication link forced, under hub processor control, to terminate. The terminated link has its associated receivers, transmitters, and steerable beam reassigned to a new user. This technique chooses the best communication path to account for path interference and fading without tying up additional equipment.

It should be readily understood by those skilled in the art that using a central control facility with the terrestrially based repeaters for monitoring and controlling the assignment of communication links will also provide the same multipath abilities. This is advantageous in environments where such obstructions as terrain, buildings and trees tend to alter the best path and the nature of the communication paths on a frequent basis.

The communication signals used in the communication system 10 are transferred by the repeaters 12 or

14 between the individual user terminals 20, 22, 24, or 26, as previously illustrated. Such terminals can in turn interface to terrestrially based communication systems or other multi-user systems. An exemplary user terminal circuit employed in the system 10 is schematically illustrated in FIG. 10.

The user terminal 130 of FIG. 9 utilizes an antenna 132 to receive and transmit communication signals which are transferred through a duplexer 144 to or from a spread spectrum receiver 146 or transmitter 166, respectively. These elements function in the same manner as those elements previously described in relation to the repeater 12 or 14 circuitry of FIG.'s 2 through 7.

The antenna used by each system 10 user will vary according to the type of service desired. A larger antenna structure can be used for fixed user terminals than for mobile users. In this case small to medium sized dish-type antennas are employed to isolate communication with one satellite and free the hub from having to make this decision or assignment. However, the communication system 10 is intended to serve a large number of users that are either truly mobile or are unable to utilize even moderately sized (2 to 4 foot diameter) antenna dishes.

In this latter application a small omni-directional antenna is contemplated. Omni-directional in this application means omni-directional in the horizontal direction. For satellite relay applications, there is a slight gain on the order of 5 dB isotropic at about 30 degrees elevation so that the antenna will direct its energy or be selective to receive energy from an elevated position. This decreases interference from energy sources that are at horizon level as would be true for adjacent cells or unrelated satellite systems. An exemplary antenna configuration is the "droopy dipole" and is shown in FIG. 11. An antenna optimized for terrestrial repeaters would preferably have more gain at lower elevation angles.

The antenna 132 of FIG. 11 employs four dipole arms 134, 136, 138, and 140 extending radially outward from a support mast 142. The dipole arms are positioned every 90 degrees around the circumference of a support post and angled downward. The exact dimension of the antenna elements depend upon the frequency to be transmitted as well as structural considerations for a mobile antenna subjected to wind drag, etc. This type of antenna is known in the communications art and it will be readily apparent to those skilled in the art how to choose the appropriate dimensions.

In order to improve the signal rejection of the antenna 112 and thereby also increase the capacity of the communication system 10, the antenna is preferably operated in a polarization selection mode. As previously discussed, the limiting factor on the capacity of the communication system 10 is the self noise or interference caused by "other" users. If some of the users are operating on another polarization, then the amount of self noise that they contribute is attenuated by the polarization isolation.

If the radiation pattern of the transmitter is perfectly circularly polarized, then the axial ratio of the receiving antenna pattern will determine the amount of interference received from an undesired polarization. The axial ratio is defined as the ratio of the minor axis to the major axis of the antenna reception pattern expressed in units of signal power. Figure 12 shows a typical pattern with an axial ratio of AR.

Ellipticity (EL) expressed in dB is related to the axial ratio by the equation:

$$EL = -10 \log_{10}(AR) \quad (4)$$

From this expression an increase in capacity for the communication system 10 as a function of the axial ratio and ellipticity can be calculated. If the voltage of a desired polarization is defined as  $1 + \sqrt{AR}$ , then the voltage of the undesired polarization is  $1 - \sqrt{AR}$ .

The increase in system capacity is the ratio of users in both polarizations to the total number of users when there is no polarization reuse. Because the self noise seen by a terminal with polarization reuse at the system 10 capacity limit equals the self noise with no polarization reuse at the system capacity limit, the following equations can be written and solved for the capacity increase K as a function of the axial ratio AR.

$$1 = \frac{k}{2} + \frac{k}{2} \left( \frac{1 - \sqrt{AR}}{1 + \sqrt{AR}} \right) \quad (5)$$

$$k = \frac{1 + 2\sqrt{AR} + AR}{1 + \sqrt{AR}} \quad (6)$$

$$K = 1 + \sqrt{AR} \quad (7)$$



The relative increase in capacity for polarization reuse is  $K-1$  or  $\sqrt{AR}$ . Figure 12 presents a plot of  $K-1$  versus ellipticity in dB. Table I of FIG. 14 lists the axial ratio, capacity increase, and polarization isolation for ellipticity from 0 to 20 dB.

Because of the unknown orientation of a mobile user and any vehicle it may be located in and the need to have some directivity in elevation, it is very difficult to get an ellipticity better than 6-10 dB. This provides a polarization isolation of 9.6-5.7 dB. This is not enough to be usable for FDMA analog or digital systems. However, because of the spread spectrum processing gain, polarization reuse can be used to increase the system capacity even though the polarization isolation is quite small or unusable by other communication systems. This combination of CDMA and polarization reuse can effectively increase the capacity of communication system 10 on the order of 50 to 80 percent.

Circularly polarized antennas are desirable in a mobile system at L-Band or lower frequencies to combat problems with Faraday rotation of the signal. Therefore, the circular polarization technique of the present invention is well suited for the mobile user terminals of the present communication system.

When the antenna 132 is operated in a polarization selection mode, the repeater antenna structure must perform complementary processing operations. Therefore, the repeaters 12 or 14 may have additional control circuitry associated with the antenna operation to control the polarization of the transmitted and received signals.

As previously discussed, phased array antennas would employ separate beam former channels for horizontal and vertical beam array elements so that left and right handed circularly polarized beams can be transmitted or received.

A polarization control signal, for selecting between the appropriate beam former used by a communication signal and, therefore, polarization modes can be generated according to the communication signal protocol designating specific users. The user polarization mode can be fixed at the time of terminal installation or by optional control circuitry.

Communication signals received on the antenna 132 are transferred to the spread spectrum receiver 146 where they are demodulated and despread to yield a digital communication signal. This digital signal is transferred through a voice/data demultiplexer 148 which separates signals into digitized voice signals or digital data signals.

The digitized voice signals are in turn transferred to a data-to-voice decoder 150 where digitized analog signals are converted to analog form using techniques known in the art. The analog output of the decoder 150, which is generally a voice signal, can be presented to a variety of subsequent circuits through an interface 152. The configuration or construction of the interface 152 depends upon the applications required by the specific user or user terminal. In typical mobile user terminals, analog signals are processed by pre-amplifiers, amplifiers, and other gain circuitry for generating high quality audible output to the system user. Such circuitry is constructed according to known principles or analog circuit design as applied to portable radio or telephone equipment and being known in the art is not described here.

Fixed user terminals would interface to other communication systems, therefore, requiring interface circuitry for connection to telephone systems, optical cable systems, or other equipment.

The digital data is transferred out of the user terminal on the data line 154 which can be connected to a modem or other interface equipment for computers or other digital equipment. Circuits for interfacing computers or other equipment for processing digital data signals are known in the electronics arts and are not described here.

Outgoing voice or analog signals are received through the interface 152 and transferred to a voice-to-data encoder 156 which generated a digitized analog signal. This digitized signal is then transferred to a voice/data multiplexer 158. The multiplexer 158 multiplexes together digitized analog signals and digital data signals to form a digital communication signal. The term multiplexing is misleading in that most user terminals will handle either voice (analog) or data at one time and not both simultaneously, although this capability is built in to the system. The need for this capability also depends on the capabilities of the receiving users.

The output of the multiplexer 158 forms the input for a transmitter 166. The digital data is brought into the user terminal on a data bus line 160.

The voice-to-data or the data-to-voice encoders can be replaced with a single element referred to in the art as a voice codec 162.

The Demand Assignment Multiple Access (DAMA) module 164 acts in concert with central control facilities to determine the ability to access the system 10 by monitoring, air time, activity, account numbers, protocol, etc. A data bus, such as data bus 168 interconnects this module with the interface 162, and additional buses such as data buses 170, 172, 174 and 176 couple the DAMA module to the voice/data multiplexing and demultiplexing devices 148 and 158, and the receiver 146 and transmitter 166, respectively.

The communication system 10 allocates power to the particular user regardless of the actual activity level. This means that for long pauses or for very low data bit rates a larger percentage of the power is being wasted in sending and receiving "empty" signals. This energy also wastes capacity since the total power available in the system limits capacity and because of the nature in how each user forms interference for other users.

Therefore, within each user terminal 130 is one or more activity detectors or monitors for sensing the data or voice activity level of the terminal user. That is, the activity level of input signals are compared to a predetermined minimum threshold level used to define an "active" input signal condition. Input signals below this threshold represent no activity and above this threshold represent activity. The transmission power is, as described previously, adjusted in response to the change in activity. In this manner the relay sees no signal during the low or non-activity time, except for occasional bursts, and can accommodate additional users.

The user terminal 130 has been described in the same terms as the repeaters 12 or 14. The user terminals utilize spread spectrum receivers and transmitters to process communication signals into and from digital data signals. The spread spectrum receivers and transmitters are the heart of the communication system 10 in that they provide the spreading and despreading function which in turn provides the processing gain and ability to use marginal isolation to achieve high quality, high capacity communications.

To achieve these results the spread spectrum receivers of the present invention use a particular demodulator circuit for despreading the incoming communication signals and generating a resulting digital signal. The demodulator circuit employed in the spread spectrum receiver 146 as shown in FIG. 10 is illustrated in further detail in FIG. 15.

In FIG. 15 a demodulator 200 constructed according to the principles of the present invention is schematically illustrated. The demodulator 200 is preceded by a downconverter 190 to change the frequency of the incoming communications signal to a lower intermediate frequency for processing using techniques or apparatus known in the art. An IF signal frequency such as, but not limited to, about 70 MHz is generally employed for communication signals in the L Band although this frequency is determined by the demands of specific applications. An incoming, RF frequency signal, 202 from the repeater 12 or 14, is processed by the downconverter 190 to provide an input, IF frequency, signal which is fed into a gain control element 204.

The gain control 204 compensates for fading and other energy alterations in the received signal which lead to degradation in processing. The gain element 204 provides a variable gain control function over an input signal and can be an electronically controlled gain device, such as would be known to those skilled in the electronics arts. For purposes of automatically controlling the gain provided by the gain control 204, a gain control signal 206 is generated by subsequent portions of the demodulator 200 as discussed further below.

This gain control function allows the demodulator 200 to operate without limiters and present the full bandwidth to the analog-to-digital converters as described below. This prevents a loss of information during processing before the conversion process. Also the gain control 204 can normalize the input signal to a predetermined level which allows the analog-to-digital conversion process to be more efficient under changing conditions and make maximum use of the bits in the analog-to-digital conversion process. This is especially useful for purposes of the present invention since the transmission signals employed are generally power limited and the receiver may be called upon to compensate for a low energy signal level when the system is handling a large number of users.

The output of the gain control 204 is connected to an RF mixer 208 in which the IF frequency input signal is mixed with a predetermined carrier frequency to yield a lower frequency analog communications signal. The demodulation frequency is provided by a frequency synthesizer 210 which can be electronically controlled as in the case of a VCO, by a carrier input adjust signal 212. Therefore, for purposes of providing a lower frequency input signal, the synthesizer 210 provides the required mixer frequency. However, as the carrier is tracked by the communication system 10 and adjustments in the carrier frequency are effected by fading, Doppler shifting, etc, the demodulator can alter the synthesizer 210 output to also compensate. This is accomplished by changing the value of the carrier input frequency adjust signal 212. As will be shown below, other portions of the demodulator automatically provide this function.

The output of the RF mixer 208, which is an analog communications signal is passed through a band pass filter 214 to remove unwanted mixer products and out of band frequency components that may be present from the downconversion process. The resulting signal 216 is an intermediate frequency analog signal which represents a narrow band information signal spread over the allocated spectral bandwidth.

While still at baseband, the signal 216 is then divided into an in-phase (I) component and a quadrature (Q) component by the phase shift divider 220. The divider 220 can further comprise a divider and phase-shifter combination as would be apparent to those skilled in the art. The I and Q signals are also referred to in the art as the 0 degree and the 90 degree components, respectively.

The I and Q signals are then transferred to separate Analog-to-Digital (A/D) converters 222 and 224, respectively. That is, the I or 0 degree component from the divider 220 provides an input to the first A/D converter

device 22 and the Q component, which is 90 degrees out of phase with the I component, provides an input for the A/D converter device 224. This configuration is used to provide more efficient conversion of the analog signal into digital form as well as improved accuracy for the later signal processing stages by breaking the Analog-to-Digital conversion process into two components.

5 In the preferred embodiment of the present invention each A/D device 22 and 224 would comprise a 4-bit converter. That is, each would convert a given portion of the analog signal 216 into a digital signal having 4-bit precision. Since the I and Q components are each converted into 4 bits of digital information and they are temporally in series, the communication link accommodates 8 bits of effective information per conversion time. The analog-to-digital conversion is divided into 4 bit increments to provide more efficient conversion since high speed 4-bit A/D converters are well developed in the art. However, the present invention does not require 4 bit increments to operate and other A/D converters may be employed where desired.

10 The A/D conversion process is clocked at a predetermined rate by a system clock 226 which also provides the appropriate timing signals used in the demodulator 200 as would be apparent to those skilled in the art who require a common in-phase clock source for other function. The clock source 226 comprises any of a number of known frequency sources or synthesizers similar to frequency synthesizer 210. The system clock must be provided with a frequency driver so that the clocking rate is twice the "chip" frequency. The frequency source is adjustable, as in the case of a VCO, so that variations in the signal link can be accommodated and the signal locked onto. For this reason a frequency adjustment input signal is provided from a source 228 discussed below.

20 The output of the two A/D devices 22 and 224 are connected to a common output data bus 230 which transfers the 0 degree and the 90 degree related four data bits in serial fashion to other parts of the demodulator 200 circuitry. The digital communications signal on data bus 230 is input to a first four-phase rotator 242 where it is combined with a pilot chip sequence which is provided from a pilot chip sequence generator 240. The resultant signal is transferred in to a first summation means 260 where the I and Q components are summed over a length of time when they are coherent.

25 Inserted into the transmitted signal is a phase coherent and chip synchronous, chip sequence that is defined as a pilot chip sequence. This pre-defined and generated chip sequence is a new method of providing phase and time acquisition and tracking, and multi-path correction.

30 In previous systems a code in the form of a tone might be used. The tone was encoded along with input data and transmitted to the receiver. Each user required a different tone. At the receiver the decoding process would reproduce the tone which could be detected using a series of filters or other elements. Any variations in the desired tone, phase or frequency, were then adjusted for accordingly. In principle this technique provides a reference signal for tuning the frequency tracking and decoding stages of a demodulator. However, the encoding and decoding of the signal and then subsequent active detection was slow, and reasonably inaccurate. Any errors in the detection or decoding of a chip sequence and/or propagation errors also create errors in a decoded tone decreasing the ability to correctly compensate or adjust the carrier and chip synchronization tracking with this technique.

40 The receiver of FIG. 15 preferably uses a time tracking error detector known in the art as a "delay-lock" detector. This detector functions by subtracting the power in an early correlation of the received signal with the local reference pilot sequence from the power in a late correlation of the received signal with the local reference pilot sequence. If there is not time tracking error, this difference signal will be zero. If the time error is such that the local reference signal leads the correct timing, then a negative difference signal will be produced. Conversely, if the local reference lags the correct timing, then a positive different error signal will be produced. The error signal is used to correct the timing in chip-time tracking loop 276.

45 The early correlation is produced in correlator 242 by correlating I and Q signals on bus 230 with the pilot chip sequence. The result is integrated in integrator 260 and the power determined by circuit 270. The late correlation is produced in correlator 246 by correlating the twice delayed signals on bus 238 with the pilot chip sequence generator 240 output. This signal is integrated by integrator 264 and power determined by circuit 274. The outputs of circuits 270 and 274 are differenced in the chip-time tracking loop 276.

50 The delay elements 232 and 236 determine the amount of time difference between the early and late correlations. Preferably, these delays are set to a value equal to 1/2 chip duration, although other values may be preferred in certain applications.

55 The carrier tracking loop operates on the output of on-time correlator 244, which correlates the output of delay element 232 with the pilot chip sequence generator 240. The correlator output is integrated in integrator 262 to provide an input to carrier tracking loop 280.

An alternate embodiment would provide early, late and on-time correlations of the received signal with the pilot sequence by delaying the pilot chip sequence generator 240 output in two 1/2 chip time delay elements and then correlating with the signals on bus 230.

The correlator means, 242, 244 and 246 are comprised of four-phase rotator elements which serve to rotate the phase of the input signal by 0, 90, 180 or 270 degrees as determined by the pilot chip sequence input bits. Circuits for accomplishing this function are readily apparent to those skilled in the communications art.

Integrator means 260, 262, and 264 integrate the outputs of their respective correlators by summing samples over an interval equal to the length of the short pilot chip sequence. Integrator 282 integrates the output of the unit chip sequence correlator 252 over an interval equal to the data symbol time. The I and Q signals output from each correlator are summed in separate integrators.

The power in a signal is determined by the circuits 284, 270 and 274. The I and Q outputs of the integrators are each squared and then summed to provide a measure of the power in the signals. Integrator 284 measures the broadband noise power on bus 234 for use in setting the receiver gain, while integrators 274 and 270 measure the power in the early and late correlations of the pilot chip sequence.

The signal 278 is coupled to the frequency synthesizer 228 as previously described and serves to alter the frequency generated in the synthesizer 228. This can be accomplished in several ways understood in the art such as establishing a predetermined voltage level in the signal 278 at the input of the synthesizer 228 which operates as a VCO. If the communication signal is late, then the tracking loop 276 establishes a lower voltage level for the signal 278 which decreases the frequency output by the synthesizer 228. On the other hand, if the communication signal is early then the voltage level of the signal 278 increases and the output frequency of the synthesizer 228 increases.

The alteration of the output frequency for the synthesizer 228 increases or decreases the timing provided by the system clock generation element 226, which in turn alters the rate at which the A/D converters 22 and 224 convert the analog data into the digital signal chip patterns.

Therefore, as the system receives an incoming communication signal and also receives a pilot chip sequence, the portion of the circuit just described allows the detection of the relative timing of the user terminal with respect to the pilot chip sequence transmission and adjustment of the Analog-to-Digital rates to account for the variations in this timing. In addition, this circuitry is used to lock onto the correct carrier frequency.

By connecting the output of the coherent summing means 262, for the "on-time", once-delayed, signal, to a carrier tracking loop 280 the carrier frequency is acquired and tracked. As the value of the summation for the on-time signal decreases it is assumed the local carrier frequency needs to be decreased. As the summation for the on-time signal increases the local carrier frequency is increased. To implement these changes, the output of the tracking loop is provided as a signal 212 which is input to the frequency synthesizer 210 as previously discussed. This changes the frequency used for the IF demodulation and causes the demodulator 200 to track the incoming carrier.

What has been described to this point is the initial operating function of the demodulator wherein the incoming communication signals are converted to a digital form and compared to the predetermined pilot chip sequence. This allows the determination of both the correct carrier frequency as well as the adjustment of the sample clock 278 to acquire the proper synchronization with the chip rate.

Once the tracking has been properly locked onto the incoming signal the actual decoding or demodulation of the data can occur to provide the user terminal with the information being transferred in the communication signals along the communication link.

The actual data or voice spread spectrum decoding is accomplished by sending the on-time signal provided by the delay element 232 on the data bus 234 to a convolutional decoder such as, but not limited to, a Viterbi algorithm decoder 290. However, the I and Q components are first summed using a summation means 282. The demodulators used in the hub 16 can also use a phase correction filter to assure that the information remains in-phase with the appropriate convolutional decoding process during the hub translation and signal processing steps.

The demodulator 200 must demodulate CDMA spread spectrum signals which means that a unique chip sequence which is used to encode or spread the input signal must be generated and used to despread the communication signal. Therefore, the incoming on-time signal provided by the A/D converters and through the delay element 232 onto bus 234 is mixed in a four-phase rotator 252 with a unit chip sequence to yield a signal only for that chip sequence corresponding to the correct user terminal.

The information is now decoded by the convolutional decoder 290 at the predetermined decoding rate to remove the interleaved error detection bits, and transferred to appropriate vocoder and other analog circuitry such as pre-amplifiers, amplifiers, and speaker systems where the user can utilize it. At this point the signal 292 can be further processed to provide additional demodulation and conversion from a digital to an analog output as known in the art. The signal would be subject to conventional amplification and gain techniques as would be useful for the receiving station.

In order to provide automatic adjustment of the gain control 204, a square and summation means 284 also receives the in-phase and quadrature signals from the data bus 234 and processes them to provide a signal

Indicative of the relative energy or power level of the signals. Since the in-phase and quadrature signals can vary greatly and change signs during initial acquisition and tracking they are first squared and then summed together to prevent cancellation. The results of this operation are transferred to an automatic gain control loop filter 286 where a control signal 206 is generated which increases or decreases the gain provided by the variable gain control 204 depending upon the decrease or increase in relative signal strength for received communication signals.

The demodulator 200 represents the basic demodulator used in the preferred embodiment of the communication system 10. However, it will be apparent to those skilled in the art that demodulation of communication signals in a repeater or a hub will not employ the pilot tracking circuitry. Furthermore, repeater and hub circuits employ narrower band filters and timing loops.

The demodulator of FIG. 15 provides a narrow band information signal from a received spread-spectrum communication signal. For the return transmission in a communication link a modulator is required in the transmitter of the user terminals 20, 22, 24, 26, repeaters 12, 14, or hubs 16.

In the transmitter 166 or the user terminal 130 illustrated in FIG 10 is a modulator 300 for generating spread spectrum CDMA communication signals for transmission. A modulator circuit and method is provided which encodes and modulates input information which can be data or voice as previously described.

A modulator circuit constructed according to the principles of the present invention is illustrated in FIG. 16. In FIG. 16 the modulator 300 receives incoming information signals 302 and inputs them into a convolutional encoder 304. The information signals 302 are processed by a voice to digital encoder, here illustrated as voice codec 162, or multiplexed in as digital data. The signals 302 are previously amplified, filtered, or processed signals originating at the user terminal and processed according to typical analog processing for communications prior to transmission.

The present invention contemplates using the latest in voice coding techniques to improve the quality of communication and allow for decreased bandwidth where possible. This translates to decreased overall power when the signal is spread, which improves system 10 capacity.

For this reason current coding schemes planned for use in the embodiments of the present invention include Linear Predictive Coding (LPC) and Continuously Variable Sloped Delta (CVSD) modulation. These techniques can accommodate data rates on the order of 4.8 to 16.0 kbps (kilo-bits per second) which is very advantageous. Current integrated circuits exist for providing these high speed coding functions in a small package or space as would be required for mobile user terminals. This handles the demand for high speed digital data encoding as well. The high speed spectrum chip frequency also handles multiples of common data rates such as 56, 32, 16, 9.6, 4.8, 2.4 kbps and down to 75 bps, thus, addressing the most desired data rates.

At a future time the communication system 10 can be changed to use other types or even slower rate encoders/decoders if desired without altering the entire communication system.

After digital encoding the information signal is transferred to a convolutional encoder 304. A convolutional encoder is understood by those skilled in the art to provide interleaving of the actual data bits forming the input signal and additional bits for ascertaining, or monitoring errors and providing for correction. The present invention allows for a variety of coding rates from 1/4 to 1/2 or more since the present invention is not constrained by the data rates.

The output of the convolutional encoder 304 is a digitally encoded information signal which is mixed with a spreading chip sequence in a four-phase rotator mixer 306.

The chip sequence is provided by a chip sequence generator 308 which generates or stores the chip sequence assigned to the user terminal 130. The assignment of user terminal chip sequences has been previously described above and is not repeated here. However, the transmitted communication signal also requires identification of the recipient in addition to the source terminal. This can be accomplished by using communication protocols known in the art.

In most communication systems the transmitting user sends a digital code representative of a recipient's telephone, radio phone, user terminal, or other unique identification number as part of an initiating communication signal. This number can be encoded in a specific pattern of data bits with accompanying control codes which indicate that a communication signal contains a receiver address and an initial communication link request. Since several protocol and link initiation code schemes which are compatible with the present invention are well understood in the art, additional circuitry used to implement them is not shown in FIG. 16.

The broad band spread information signal produced by the mixer 306 operation is transferred to an RF mixer 312 where it is mixed with a carrier frequency to produce the communication signals to be transmitted. The carrier frequency is provided by or generated in a frequency synthesizer 310. The specific frequency used is predetermined by the spectral allocation for the communication system 10 as well as any special spectral allocations for particular users. However, the frequency source 310 is adjustable so that the effects of Doppler shifting can be compensated for on the uplink side of a communication link.

This is accomplished by observing apparent changes in the carrier frequency detected by the demodulator 200 in the receiver 146. As previously described, a carrier tracking signal 212 is generated in the demodulator 200 which is indicative of variations in the received carrier tracking frequency in relation to a local carrier frequency. This same signal can be coupled to the frequency synthesizer 310 to adjust the carrier frequency used for transmission. As the carrier is observed by the receiver to vary due to a variety of effects, the transmitter automatically adjusts the return link to also compensate. In this manner, a repeater does not perceive a change, or very little change, in carrier tracking due to Doppler and other effects. Therefore, user terminals, even though mobile, appear substantially stationary to communication system 10 repeaters and do not require compensation in the repeater.

The communication signal provided by the mixer 312 is coupled into a transmit analog bandpass filter 316 which acts to filter out undesirable frequencies which are outside of the range of the target system and represent a loss of useful transmission power.

The output of the bandpass filter 316 is coupled to a transmit power control device 318 which provides the final amplification and control of transmission power for the communication signal presented to an antenna.

The power control device 318 is adjustable both in terms of overall power level and duty cycle or duration.

The relative strength of received communication signals can be determined in the demodulator 200 such as in the automatic gain control loop filter 286. From this a control signal can be provided to a fade and power adjust control circuit 320. The control circuit 320 detects the increase or decrease in signal strength according to a signal 206 and provides an appropriate control signal 322 to the transmit power control device 318 to either increase or decrease output power. This allows the user terminal to compensate for changes in relative position with respect to a repeater as well as some degree of fading without requiring additional power compensation schemes in the repeater circuitry. Therefore, the repeater observes the signal strength of the user terminal as if the terminal is in a fixed location. Alternatively, a repeater can of course, use a fixed control signal to indicate fading of received signals and send information to the control device 318 as part of the pilot sequence or communication protocol to instruct it to compensate subsequent communications.

As previously discussed the user terminals 20, 22, 24, and 26 employ a speech, voice, analog signal, or digital signal activity detector to decrease the amount of unnecessary power consumed and interference generated. To accomplish this an activity detector 324 is provided, here labeled as a voice activated switch (VOX), which is coupled to the input signal 302 or the output of the convolutional encoder 304. For purposes of illustration a voice signal is described but a digital input signal can also be accommodated by the modulator 300 and the VOX 324.

The VOX 324 detects the general activity level of the input information signal and determines when the output transmission can be turned off due to a lack of activity. The amount of power required or available in a communication system, as well as the amount of capacity increase desired, determine the length of periods of "non-activity" that are chosen. The VOX 324 provides a control signal to the power control device 318 which instructs it to alter the duty cycle for transmission signals. In this manner only short periodic bursts are sent by the transmitter when there is no activity. This allows the communication system 10 to continue maintaining and tracking the communication link for the user terminal 130 while not wasting power and, therefore, communication system 10 capacity.

The output leaving the power control device 318 is transferred to the appropriate antenna structure employed by the user terminal 130. The modulator 300 has been described in terms of generating a communication signal at the desired carrier frequency. Alternatively, the frequency synthesizer 310 provides an intermediate frequency from the mixer 312. In this case an upconverter stage is disposed between the power control device 318 and any antenna to upconvert the output communication signals to the appropriate carrier frequency for the communication system 10.

In addition to the power control, the frequency synthesis and the timing used for the bit and symbol clocks are adjustable to compensate for the Doppler shift and fading effects found primarily in mobile systems. That is, the demodulator 200 tracking loops are used to provide signals to the modulator 300 to alter the frequency generated by a frequency synthesizer 328 which in turn drives the modulator 300 clock generation device 328.

What has been described then is a new communication system employing CDMA spread spectrum processing techniques. The user terminals and repeaters for the communication system use a new modulator and demodulator design to transmit and receive communication signals. The user terminals and repeaters use means for creating marginal isolation between user communication signals such as, but not limited to, multiple beam phased array repeater antennas, polarization enhanced omni-directional antennas, voice or activity switching, or adjustable user terminal power control to increase the capacity of the system.

The repeaters for the communication links are orbital or terrestrially based repeater stations that can provide a variety of communication paths to compensate for Doppler shifts, and multi-path problems found in other communication systems. The orbital and terrestrial repeaters can interconnect to offload users from each other

and cover selected geographical regions of user classes where desired. The use of multiple beam antennas further increases system capacity and provides an ability to uniquely control communication links within the system.

It will be appreciated by those skilled in the art that additional means or methods of providing marginal isolation between users can be used. Also alternate methods of providing spread spectrum waveforms other than those specifically discussed herein are contemplated by the present invention.

The preferred embodiment has been described utilizing one or more repeaters for ease of illustration that demonstrates the advantages as an initial system. However, a communication network employing direct user-to-user links with marginal isolation is also contemplated by the present invention.

The foregoing description of preferred embodiments has been presented for purposes of illustration and description. It is not intended to be exhaustive nor to limit the invention to the precise form disclosed, and many modifications and variations are possible in light of the above teaching. The embodiments were chosen and described to best explain the principles of the invention and its practical application to thereby enable others skilled in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated.

### Claims

1. A multiple access, spread-spectrum communication system (10,30), comprising means for communicating information signals between at least two of a plurality of system users (20,22,24,26), using corresponding code-division-spread-spectrum communication signals, and characterised by isolation means coupled to the means for communicating for unequally weighting signal power of the spread-spectrum communication signals.
2. A system according to claim 1, characterised in that the isolation means comprises a phased array antenna (68) coupled to the means for communicating for generating substantially simultaneous multiple steerable beams.
3. A system according to claim 1, characterised in that the isolation means comprises an antenna structure (132) configured to obtain polarization mode selection between a plurality of polarization modes.
4. A system according to claim 1, characterised in that the isolation means comprises a power control means (270,284,318) for adjusting an output power duty cycle for the spread-spectrum communication signals in response to an activity level of the information signals.
5. A system according to claim 1, characterised in that the isolation means comprises transmission means (56,86,100,166) for transmitting each of the spectrum communication signals from two or more spaced apart locations (20,22,24,26), with a phase and time relationship between transmission from the spaced apart locations so as to generate interference patterns having a maximum signal-to-noise ratio for the spread-spectrum communication signals at a receive location.
6. A system according to claim 1, characterised in that the isolation means comprises power control means (274) for adjusting an output power level for said spread-spectrum communication signals in response to a minimum power level required to complete a communication link.
7. A system according to claim 1, characterised in that the means for communicating further comprises:
  - chp generation means (240,308) for generating a plurality of quasi-orthogonal spreading functions;
  - code selection means for assigning one of the spreading functions to a user;
  - a plurality of mobile user terminals (20,22) capable of transmitting or receiving the spread-spectrum communication signals, each of the said user terminals (20,22) comprising:
    - transmission means (56,86,100,166) for generating a code-division-spread-spectrum communication signal in response to an input information signal according to an assigned spreading function,
    - receiver means (42,44,84) for generating an output information signal by processing a received code-division-spread-spectrum communication signal according to the assigned spreading function, and
    - at least one omni-directional antenna (66,92, 132) coupled to the transmission means (56,86,100, 166) and the receiver means (42,44,84); and



at least one repeater means (12,14,60) for receiving code-division-spread-spectrum communication signals from the plurality of user terminals (20,22) and for translating the code-division-spread-spectrum communication signals to a form suitable for transfer to an intended recipient user.

- 5 8. A system according to claim 7, characterised in that the repeater means (12,14,60) further comprises means (240,308) for transmitting a predetermined pilot chip sequence to said users.
9. A system according to claim 7, characterised in that the said at least one repeater means (12,14, 60) further comprises a phased array antenna system (68) capable of generating simultaneous steerable beams.
- 10 10. A system according to claim 7, characterised in that the said at least one repeater means comprises at least one terrestrially based repeater means (12) centrally located within a geographical region.
11. A system according to claim 7, characterised in that the said at least one repeater means comprises at least one satellite based repeater means (14).
- 15 12. A system according to claim 7, further characterised by at least one central communication station (16) for receiving communication signals from said repeater means (12,14,60) for transfer to an intended recipient user and for transmitting communication signals to the repeater means (12,14,60) for translation and transfer to an intended recipient user terminal (20,22,24,26).
- 20 13. A system according to claim 7, characterised in that the repeater means (12,14,60) comprises: at least one terrestrially based repeater (12) for receiving, translating and retransmitting the spread-spectrum communication signals; at least one satellite based repeater (14) for receiving, translating and retransmitting the spread-spectrum communication signals; and in that the user terminals (20,22,24,26) are configured to transmit and receive code-division-spread-spectrum communication signals through either repeater (12,14) which repeater (12,14) is configured to receive or transmit code-division-spread-spectrum communication signals from or to the user terminals (20,22,24,26).
- 25 14. A system according to claim 7, characterised in that the transmission means (324) further comprises activity detection means for sensing signal activity levels in the said input information signal and decreasing user terminal transmission power duty cycle in response to a decrease in sensed activity below a predetermined threshold level for a predetermined sampling time.
- 30 15. A system according to claim 8, characterised in that the repeater means (12,14,60) further comprises activity detection means (324) for sensing signal activity levels in the spread-spectrum communication signals and decreasing repeater transmission power duty cycle in response to a decrease in sensed activity below a predetermined threshold level for a predetermined sampling time.
- 35 16. A system according to claim 7, characterised in that receiver means further comprises link power control means (318,320) for sensing a received power level present in received first code-division-spread-spectrum communication signals and for adjusting power applied to an antenna (66,92,132) for transmitting second code-division-spread-spectrum communication signals in response to the sensed power level.
- 40 17. A system according to claim 7, characterised by polarization control means (110) coupled to said omnidirectional antenna (66,92,132) for adjusting the antenna so as to select a predetermined polarization mode from a plurality of polarization modes.
- 45 18. The communication system of claim 7, characterised in that said receiver means further comprises a demodulator (200), comprising:
  - 50 input means for receiving code-division-spread-spectrum communication signals;
  - a variable frequency source (210) generating a local reference signal of predetermined frequency;
  - a radio frequency mixer (208) connected to said input means and said variable frequency source (210) for mixing the code-division-spread-spectrum communication signals with the local reference signal to provide an intermediate spread spectrum signal;
  - 55 filter means (214) connected in series with said radio frequency mixer (208) for filtering undesirable frequency components from said intermediate spread spectrum signal,
  - phase division means (220) connected in series with said filter means (214) for dividing said spread

spectrum signal into an analog in-phase signal and an analog quadrature signal;

converter means (222,224) connected to said phase division means for converting said analog in-phase and quadrature signals to digital in-phase and quadrature signals at a variable rate;

combiner means connected to an output of said converter means (222,224) for juxtaposing said digital in-phase and quadrature signals onto a single data line for transfer to other components within said demodulator (200) in serial fashion;

pilot chip reference means (240) for generating a local bit sequence corresponding to a predetermined pilot chip sequence transmitted contiguous with communication signals received by said demodulator (200) said local bit sequence being generated with a predetermined period;

carrier tracking means (280) connected to said combiner means and said pilot reference means (240) for comparing said local pilot chip sequence to received signals in a timed relationship to determine the timing of said code-division-spread-spectrum communication signals with respect to said local pilot chip sequence and for adjusting the frequency of said variable frequency source (210);

chip time tracking means connected to said combiner means and said pilot reference means (240) for comparing said local pilot chip sequence to received signals in a plurality of timed relationships to determine the timing of said code-division-spread-spectrum communication signals with respect to said local pilot chip sequence and for adjusting the rate for said converter means;

unit chip means (250) for generating a bit sequence corresponding to said assigned spreading function;

despreading means (252) connected to said combiner and said unit chip means for generating despread-spectrum in-phase and quadrature information signals; and

output means (290) connected to said despreading means (252) for combining said despread-spectrum in-phase and quadrature signals into an output information signal.

19. The system of claim 18, characterised in that said carrier tracking means (280) and said chip-time tracking means further comprise:

first correlation means (242) connected to said combiner means and said pilot reference means (240) for comparing said digital in-phase and quadrature signals with said pilot chip sequence and providing an output representative of a first correlation pattern;

second correlation means (244) connected to said combiner means and said pilot reference means (240) for delaying said digital in-phase and quadrature signals an amount of time on the order of half said pilot chip period and comparing said digital in-phase and quadrature signals with said pilot chip sequence and providing an output representative of a second correlation pattern;

third correlation means (246) connected to said combiner means and said pilot reference means (240) for delaying said digital in-phase and quadrature signals an amount of time on the order of said pilot chip period and comparing said digital in-phase and quadrature signals with said pilot chip sequence and providing an output representative of a third correlation pattern;

chip synchronization means (270,274) connected to said first and third correlation means for adjusting the rate of said converter means in response to the output provided by said first correlation and third correlation means; and

a carrier tracking loop (280) connected to said second correlation means (244) for adjusting said variable frequency source in response to the output provided by said second correlation means (244).

20. The system of claim 18, further characterised by a variable gain control (204) disposed between and connected in series with said input means (190) and said radio frequency mixer (208) and automatic gain control means (206) connected to said combiner means for altering the gain of said variable gain control (204) in response to an absolute magnitude of said in-phase and quadrature signals.

21. The system of claim 18, characterised in that said converter means (222,224) comprises first analog conversion means (222) for converting said in-phase signal to a digital in-phase signal and second analog conversion means (224) for converting said quadrature signal to a digital quadrature signal.

22. The system of claim 19, characterised in that said first correlation means comprises:

first means (242) for multi-phase mixing said digital in-phase and quadrature signals with said pilot chip sequence;

first coherent summation means (260) coupled to said first means for multi-phase mixing (242), for generating the sum of said digital in-phase and quadrature signals coherently over a predetermined period of time; and

first squared summation means (230) for generating the sum of the square of said digital in-phase and quadrature signals over a predetermined period of time.

23. The system of claim 22, characterised in that said second correlation means comprises:  
5        second means (244) for multi-phase mixing said digital in-phase and quadrature signals with said pilot chip sequence;  
         first delay means (232) positioned between said combiner means and said second means (244) for multiphase mixing; and  
         second coherent summation means (262) coupled to said second means (244) for multi-phase mixing, for generating the sum of said digital in-phase and quadrature signals coherently over a predetermined period of time.  
10
24. The system of claim 23, characterised in that said third correlation means comprises:  
         third means (246) for multi-phase mixing said digital in-phase and quadrature signals with said pilot chip sequence;  
15        second delay means (236) positioned between said first delay means (232) and said third means (246) for multi-phase mixing;  
         third coherent summation means (264) coupled to said third means (246) for multi-phase mixing, for generating the sum of said digital in-phase and quadrature signals coherently over a predetermined period of time; and  
20        second squared summation means (274) for generating the sum of the square of said digital in-phase and quadrature signals over a predetermined period of time.
25. The communication system of claim 7, characterised in that said receiver means further comprises a demodulator (200), comprising:  
25        input means (214) for sampling substantially the entire bandwidth of said code-division-spread-spectrum signals;  
         phase division means connected in series with said input means for dividing said spread spectrum signal into an analog in-phase signal and an analog quadrature signal;  
30        converter means (222,224) connected to said phase division means for converting said analog in-phase and analog quadrature signals to digital in-phase and quadrature signals at a variable rate.
26. A system according to claim 1, characterised in that the spread-spectrum communication signals are transferred over at least one communication channel and the isolation means provides isolation between co-channel signals in the range of about 1 dB to 15 dB.  
35
27. A system according to claim 1, characterised in that the means for communicating is configured to communicate information signals from at least one central communication station (16) to at least one remote system user.
- 40 28. A system according to claim 1, characterised in that the means for communicating is configured to communicate information signals from at least one remote system user to at least one central communication station (16).
29. A method of providing high capacity multiple access communications to a plurality of communication service users, comprising the steps of:  
45        converting a plurality of narrow band input information signals into a plurality of wide band user addressable code-division-spread-spectrum communication signals, using an assigned spreading function, and a predetermined carrier frequency; and  
         communicating the code-division-spread-spectrum communication signals between users; and  
50        characterised by the steps of:  
         weighting signal power unequally in communication of the spread-spectrum communication signals, with signals directed to an intended recipient user of greater average signal strength with respect to interfering signals directed to other users; and  
         converting each received address corresponding code-division-spread-spectrum communication signal to a corresponding narrow band information signal.  
55
30. A method according to claim 29, characterised by communicating a pilot chip sequence comprised of a predetermined sequence of data bits.

31. A method according to claim 29, characterised in that the said step of communicating comprises the step of relaying the spread-spectrum communication signals between users through at least one repeater.
- 5 32. A method according to claim 31, characterised in that the step of relaying comprises the steps of receiving and transmitting the spread-spectrum communication signals by at least one terrestrial repeater (12).
33. A method according to claim 31, characterised in that the step of relaying comprises the steps of receiving and transmitting the spread-spectrum communication signals by at least one satellite repeater (14).
- 10 34. A method according to claim 31, characterised in that the step of relaying comprises the steps of receiving and transmitting the spread-spectrum communication signals by at least one terrestrial repeater (12) and at least one satellite repeater (14).
- 15 35. A method according to claim 29, characterised in that the step of weighting signal power unequally comprises the steps of receiving or transmitting spread-spectrum communication signals through an antenna array (66,92,132) forming multiple steerable beams.
36. A method according to claim 29, characterised in that the step of weighting signal power unequally comprises the step of establishing polarization modes in an antenna (66,92,132).
- 20 37. A method according to claim 29, characterised in that the step of weighting signal power unequally comprises the step of decreasing transmission signal power for a user during periods of low input information signal activity.
- 25 38. A method according to claim 29, characterised in that the step of weighting signal power unequally comprises the step of adjusting transmission signal power applied to a code-division-spread-spectrum communication signal to a minimum power level required to establish and maintain a communication link.
- 30 39. A method according to claim 29, characterised in that the step of weighting signal power unequally comprises the steps of transmitting or receiving a same said code-division-spread-spectrum communication signal through at least two spaced apart locations, so that interference patterns are generated which maximize a signal-to-noise ratio for the code-division-spread-spectrum communication signals at an intended recipient user.
- 35 40. A system according to any of claims 1 to 28, characterised in that the system has high system user capacity, and comprises means for communicating system user addressable information signals between at least two of a plurality of system users using address corresponding code-division-spread-spectrum communication signals, the means for communicating generating mutual interference in communications between the said at least two system user by contemporaneously communicating code-division-spread-spectrum communication signals between other system users, and the means for communicating having a processing gain for reducing the mutual interference; and further including isolation means, coupled to the means for communicating, for providing an increase in system user realized average signal power for the system user address corresponding code-division-spread-spectrum communication signals in communications between the said at least two system users relative to mutual interference signal power of the contemporaneous communications between the other system users.
- 40 41. A system according to claim 40, characterised in that the isolation means comprises an antenna system (68) having an antenna beam pattern forming multiple directive beams.
- 45 42. A system according to claim 40, characterised in that the isolation means comprises an antenna system (132) configured to obtain polarization mode selection between a plurality of polarization modes.
- 50 43. A system according to claim 40, characterised in that the isolation means comprises:  
actively detection means (324) for measuring signal activity levels for the information signals relative to a no activity level over a predetermined sampling time and for providing an activity signal corresponding to measured activity; and  
55 power control means (318) coupled to the means for communicating for adjusting a transmission power duty cycle for the spread-spectrum communication signals in response to changes in the activity signal.

44. A system according to claim 40, characterised in that the isolation means comprises interference pattern means for generating interference patterns of maximum signal-to-noise ratio at a receive location in communicated code-division-spread-spectrum communication signals, the interference pattern means (56,86,100,166) having transmission means for transmitting a same communication signal via at least two different communication paths to the receive location and control means (44) coupled to the transmission means for adjusting signal phase or transmission start times in the transmissions of the same communication signal transmitted via the different communication paths.
45. A system according to claim 40, characterised in that the means for communicating further communicates a same communication signal via at least two different communication paths and the isolation means comprises signal combination means for coherently combining the same communication signal as received at a receive location from the different communication paths, the signal combination means having reception means for receiving each of the same communication signals as transmitted via each of the different communication paths and control means coupled to the reception means for adjusting signal phase or timing in receptions of the same communication signal via the different communication paths.
46. A system according to claim 40, characterised in that the means for communicating comprises:  
 a plurality of terrestrially based repeater means (12) for transmitting the spread-spectrum communication signals;  
 a plurality of transceiver means each coupled to a respective one of certain system users for receiving the spread-spectrum communication signals and for transmitting system user addressed code-division-spread-spectrum communication signals;  
 the plurality of repeater means (12) further for receiving transceiver means transmitted code-division-spread-spectrum communication signals; and in that  
 the isolation means comprises the placement of each repeater means (12) at a predetermined position with respect to each other repeater means (12), each repeater means (12) in communicating with at least one of the said certain system users within a predetermined respective geographic region using the code-division-spread-spectrum communication signals with mutual interference signal power from communications in adjacent geographic regions attenuated as a function of distance therefrom.
47. A system according to claim 40, characterised in that the means for communicating further comprises:  
 link control means (320) for detecting a minimum power level required to maintain code-division-spread-spectrum communication signals in a user communication link above a predetermined incident power level and for providing a link control signal corresponding to the said minimum power level;  
 power control means (318) connected to the communication means and the link control means for adjusting a transmission power level for the code-division-spread-spectrum communication signals in response to the link control signal.
48. A system according to claim 40, characterised in that the means for communicating further comprises:  
 chip generation means (240,308) for generating a plurality of quasi-orthogonal spreading functions;  
 code selection means for assigning one of the spreading functions to a user;  
 a plurality of mobile user terminals (20,22) capable of transmitting and receiving the spread-spectrum communication signals, each of the user terminals (20, 22) comprising:  
 transmission means (56,86,100,166) for generating, according to an assigned spreading function, a code-division-spread-spectrum communication signal in response to an input information signal;  
 receiver means (42,44,84) for generating an output information signal by processing a received code-division-spread-spectrum communication signal according to the assigned spreading function; and  
 at least one omni-directional antenna (66,92, 132) for coupling to the transmission means and the receiver means; and  
 at least one repeater means (12,14,60) for receiving code-division-spread-spectrum communication signals from the plurality of user terminals (20,22) and for translating the received code-division-spread-spectrum communication signals to a form suitable for transfer to an intended recipient user.
49. A method according to any of claims 29 to 39 for providing high system user capacity in a spread-spectrum multiple access communication system in which system users communicate user addressable information

signals using address corresponding code-division-spread-spectrum communication signals in which, with respect to communications between at least two system users, other system users generate mutual interference by contemporaneously communicating code-division-spread-spectrum communication signals with the said system having a processing gain for reducing mutual interference, the method further reducing mutual interference in communications between the said at least two system users and being characterised by the steps of:

5 providing a plurality of system user addressable narrow band information signals;  
 converting the plurality of system user addressable narrow band information signals into a corresponding plurality of system user address corresponding wide band code-division-spread-spectrum communication signals;

10 transmitting the plurality of code-division-spread-spectrum communication signals between system users; receiving, at each respective system user, system user address corresponding code-division-spread-spectrum communication signals and other respective system user addressed code-division-spread-spectrum communication signals as mutual interference;

15 providing for each respective system user an increase in system user realized average signal power for the system user address corresponding code-division-spread-spectrum communication signals with respect to mutual interference signal power of the other system user address corresponding code-division-spread-spectrum communication signals; and

20 converting, at each respective system user, received address corresponding code-division-spread-spectrum communication signals into corresponding user addressable information signals.

50. A method according to claim 49, characterised in that the step of providing an increase in signal power comprises the steps of:

25 providing an antenna system (68) having an antenna beam pattern forming multiple directive beams with each beam corresponding to certain system users; and

radiating each system user address corresponding code-division-spread-spectrum communication signals on each of the beams corresponding to each system user to which the radiated system user address corresponding communication signal corresponds.

30 51. A method according to claim 49, characterised in that the step of providing an increase in signal power comprises the steps of:

providing an antenna system (68) having an antenna beam pattern forming multiple directive beams with each beam corresponding to certain system users; and

35 collecting upon each beam code-division-spread-spectrum communication signals from the corresponding system users which correspond to each respective beam.

52. A method according to claim 49, characterised in that the step of providing an increase in signal power comprises the step of providing each system user with a polarization mode selectable antenna set to receive transmitted code-division-spread-spectrum communication signals according to a predetermined one of a plurality of polarization modes where address corresponding code-division-spread-spectrum communication signals are transmitted according to a polarization mode to which the antenna system of each address corresponding system user is set to receive.

53. A method according to claim 49, characterised in that the step of providing an increase in signal power comprises the steps of:

45 measuring signal activity levels for the information signals relative to a no activity level of a predetermined sampling time;

providing an activity signal corresponding to the measured activity levels; and

50 adjusting a transmission power duty cycle for the spread-spectrum communication signals in response to changes in the activity signal.

54. A method according to claim 49, characterised in that the step of providing an increase in signal power comprises the steps of:

55 transmitting, in the step of transmitting, a same system user address corresponding code-division-spread-spectrum communication signal via at least two different communication paths to an address corresponding system user located at a receive location; and

adjusting in the transmission of the same communication signal one of signal phase and signal transmission delay time as transmitted upon the different communication paths, wherein an interference

pattern occurs having a maximum signal-to-noise ratio in the transmitted same communication signals at the receive location.

55. A method according to claim 49, characterised in that said step of providing an increase in signal power comprises the steps of:
- receiving at a system user located at a receive location a same system user address corresponding code-division-spread-spectrum communication signal as transmitted upon at least two different communication paths in the step of transmitting; and
- coherently combining the same communication signal as received upon the different communication paths by adjusting at least one of signal phase and signal reception delay time of the said same communication signal as received upon the different communication paths.
56. A method according to claim 49, characterised in that the step of transmitting comprises the steps of:
- providing a plurality of terrestrially based repeaters (12) each capable of transmitting the spread-spectrum communication signals;
- providing for certain system users a transceiver capable of transmitting and receiving the spread-spectrum communication signals; and in that
- the step of providing an increase in signal power comprises the step of placing each repeater (12) at a predetermined position with respect to other repeaters (12) wherein each repeater (12) communicates with at least one of the certain system users within a predetermined respective geographic region using the spread-spectrum communication signals with mutual interference signal power from communications in adjacent geographic regions attenuated as a function of distance therefrom.
57. A method according to claim 49, further characterised by:
- detecting a minimum power level required to maintain system user address corresponding code-division-spread-spectrum communication signals in a system user communication link above a predetermined incident power level;
- providing a link control signal corresponding to the detected minimum power level; and
- adjusting a transmission power level for the system user address corresponding code-division-spread-spectrum communication signals in response to the link control signal.

#### Patentansprüche

1. Vielfachzugriffs-Spread-Spektrum-Kommunikationssystem (10, 30) mit Einrichtungen zum Informationssignal-Austausch zwischen mindestens zwei aus einer Vielzahl von Systembenutzern (20, 22, 24, 26), die entsprechende Code-Trennungs-Spread-Spektrum-Kommunikationssignale benutzen, gekennzeichnet durch
- eine mit den Kommunikationseinrichtungen verbundene Trenneinrichtung zur ungleichen Gewichtung der Signalleistung der Spread-Spektrum-Kommunikationssignale.
2. System nach Anspruch 1, dadurch gekennzeichnet, daß die Trenneinrichtung ein mit den Kommunikationseinrichtungen verbundenes phasengesteuertes Antennenfeld (68) zur Erzeugung von im wesentlichen simultanen, vielfachen, richtungsverstellbaren Strahlen aufweist.
3. System nach Anspruch 1, dadurch gekennzeichnet, daß die Trenneinrichtung eine Antennenstruktur (132) aufweist, die so konfiguriert ist, daß Polarisationsmoden-Auswahl aus einer Vielzahl von Polarisationsmoden erreicht wird.
4. System nach Anspruch 1, dadurch gekennzeichnet, daß die Trenneinrichtung eine Leistungs Regelungseinrichtung (270, 284, 318) zur Einstellung eines Ausgangsleistungsspiels für die Spread-Spektrum-Kommunikationssignale in Abhängigkeit vom Aktivitätspegel der Informationssignale aufweist.
5. System nach Anspruch 1, dadurch gekennzeichnet, daß die Trenneinrichtung Übertragungseinrichtungen (56, 86, 100, 166) für die Übertragung jedes der Spektrum-Kommunikationssignale von zwei oder mehr räumlich voneinander entfernten Orten (20, 22, 24, 26) aufweist, mit einer Phasen- und Zeitbeziehung zwischen dem Senden von den räumlich voneinander entfernten Orten, so daß Interferenzmuster erzeugt werden, die ein maximales Signal/Rausch-Verhältnis für die Spread-Spektrum-Kommunikationssignale an einem Empfangsort haben.



6. System nach Anspruch 1, dadurch gekennzeichnet, daß die Trenneinrichtung eine Leistungs-Regelungseinrichtung (274) zur Einstellung eines Ausgangsleistungspegels für die Spread-Spektrum-Kommunikationssignale in Abhängigkeit vom minimalen, zur Herstellung einer Kommunikationsverbindung erforderlichen Leistungspegel aufweist.
7. System nach Anspruch 1, dadurch gekennzeichnet, daß die Kommunikationseinrichtung ferner enthält:
- Chipeinrichtungen (240, 308) zur Erzeugung einer Vielzahl quasi-orthogonaler Ausbreitungsfunktionen;
  - eine Codeauswahleinrichtung zur Zuweisung einer der Ausbreitungsfunktionen an einen Benutzer;
  - eine Vielzahl mobiler Benutzerterminals (20, 22), die in der Lage sind, Spread-Spektrum-Kommunikationssignale zu senden oder zu empfangen, wobei jedes der Benutzerterminals (20, 22) folgendes aufweist:
    - Übertragungseinrichtungen (56, 86, 100, 166) zur Erzeugung eines Code-Teilungs-Spread-Spektrum-Kommunikationssignals in Abhängigkeit von einem Eingangs-Informationssignal entsprechend einer zugewiesenen Ausbreitungsfunktion,
    - Empfangseinrichtungen (42, 44, 84) zur Erzeugung eines Ausgangs-Informationssignals durch Verarbeitung eines empfangenen Code-Teilungs-Spread-Spektrum-Kommunikationssignals entsprechend der zugewiesenen Ausbreitungsfunktion und mindestens einer mit den Übertragungseinrichtungen (56, 86, 100, 166) und den Empfangseinrichtungen (42, 44, 84) verbundenen, ungerichteten Rundstrahlantenne (66, 92, 132) und
    - mindestens eine Umsetzeinrichtung (12, 14, 60) zum Empfang von Code-Teilungs-Spread-Spektrum-Kommunikationssignalen von der Vielzahl der Benutzerterminals (20, 22) und zum Umsetzen der Code-Teilungs-Spread-Spektrum-Kommunikationssignale in eine für die Übertragung an einen bestimmten Empfangsbenutzer geeigneten Form.
8. System nach Anspruch 7, dadurch gekennzeichnet, daß die Umsetzeinrichtung (12, 14, 60) ferner Einrichtungen (240, 308) zum Senden einer vorbestimmten Steuer-Chipsequenz an die Benutzer aufweist.
9. System nach Anspruch 7, dadurch gekennzeichnet, daß mindestens eine der Umsetzeinrichtungen (12, 14, 60) ferner ein phasengesteuertes Antennenfeldsystem (68) aufweist, das in der Lage ist, simultane, richtungsgesteuerte Strahlen zu erzeugen.
10. System nach Anspruch 7, dadurch gekennzeichnet, daß mindestens eine der Umsetzeinrichtungen mindestens eine, zentral in einer geographischen Region angeordnete, erdgestützte Umsetzeinrichtung (12) aufweist.
11. System nach Anspruch 7, dadurch gekennzeichnet, daß mindestens eine der Umsetzeinrichtungen mindestens eine satellitengestützte Umsetzeinrichtung (14) aufweist.
12. System nach Anspruch 7, ferner gekennzeichnet durch mindestens eine zentrale Kommunikationsstation (16) zum Empfang von Kommunikationssignalen von den Umsetzeinrichtungen (12, 14, 60) zur Übertragung an einen ausgewählten Empfangsbenutzer und zum Senden von Kommunikationssignalen an die Umsetzeinrichtungen (12, 14, 60) zur Umsetzung und zur Übertragung an ein ausgewähltes Empfangsbenutzerterminal (20, 22, 24, 26).
13. System nach Anspruch 7, dadurch gekennzeichnet, daß die Umsetzeinrichtung (12, 14, 60) folgendes aufweist:
- mindestens einen erdgestützten Umsetzer (12) zum Empfangen, Umsetzen und Wieder-Aussenden der Spread-Spektrum-Kommunikationssignale;
  - mindestens einen satellitengestützten Umsetzer (14) zum Empfangen, Umsetzen und Wieder-Aussenden der Spread-Spektrum-Kommunikationssignale, und
- daß die Benutzerterminals (20, 22, 24, 26) so konfiguriert sind, daß sie zum Senden und Empfangen der Code-Teilungs-Spread-Spektrum-Kommunikationssignale über einen der beiden Umsetzer (12, 14) geeignet sind, wobei die Umsetzer (12, 14) Code-Teilungs-Spread-Spektrum-Kommunikationssignale von den Benutzerterminals (20, 22, 24, 26) empfangen bzw. zu diesen senden können.
14. System nach Anspruch 7, dadurch gekennzeichnet, daß die Übertragungseinrichtung (324) ferner eine Aktivitätsmessungseinrichtung zur Messung des Signal-Aktivitätspegels in dem Eingangs-Informationssignal und zur Verringerung des Benutzerterminal-Sendeleistungsspiels als Reaktion auf ein Absinken

der gemessenen Aktivität unter einen bestimmten Schwellenpegel für eine vorbestimmte Abtastzeit aufweist.

- 5 15. System nach Anspruch 8, dadurch gekennzeichnet, daß die Umsetzeinrichtung (12, 14, 60) ferner eine Aktivitätsmessungseinrichtung (324) zur Messung des Signal-Aktivitätspegels in den Spread-Spektrum-Kommunikationssignalen und zur Verringerung des Umsetzer-Sendeleistungsspiels als Reaktion auf das Absinken der gemessenen Aktivität unter einen vorbestimmten Schwellenpegel für eine vorbestimmte Abtastzeit aufweist.
- 10 16. System nach Anspruch 7, dadurch gekennzeichnet, daß die Empfangseinrichtung ferner Verbindungsleistungs-Regeleinrichtungen (318, 320) zur Messung eines in empfangenen ersten Code-Teilungs-Spread-Spektrum-Kommunikationssignalen vorhandenen empfangenen Leistungspegels und zur Einstellung der an die Antenne (66, 92, 132) angelegten Leistung zum Senden zweiter Code-Teilungs-Spread-Spektrum-Kommunikationssignale in Abhängigkeit von dem gemessenen Leistungspegel aufweist.
- 15 17. System nach Anspruch 7, gekennzeichnet durch eine Polarisations-Regeleinrichtung (110), die mit der ungerichteten Rundstrahlantenne (66, 92, 132) verbunden ist, um die Antenne so einzustellen, daß ein vorbestimmter Polarisationsmodus aus einer Vielzahl von Polarisationsmoden ausgewählt wird.
- 20 18. Kommunikationssystem nach Anspruch 7, dadurch gekennzeichnet, daß die Empfangseinrichtung ferner einen Demodulator (200) aufweist, der folgendes aufweist:
  - eine Eingangseinrichtung zum Empfang von Code-Teilungs-Spread-Spektrum-Kommunikationssignalen;
  - 25 - eine variable Frequenzquelle (210), die ein lokales Referenzsignal vorbestimmter Frequenz erzeugt;
  - einen HF-Mischer (208), der an die Eingangseinrichtung und an die variable Frequenzquelle (210) angeschlossen ist und zum Mischen der Code-Teilungs-Spread-Spektrum-Kommunikationssignale mit dem lokalen Referenzsignal dient, um ein intermediäres Spread-Spektrums-Signal bereitzustellen;
  - 30 - eine Filtereinrichtung (214), die in Reihe mit dem Radiofrequenzmischer (208) geschaltet ist und dem Ausfiltern unerwünschter Frequenzkomponenten aus dem intermediären Spread-Spektrums-Signal dient;
  - eine Phasenteilereinrichtung (220), die in Reihe mit der Filtereinrichtung (214) geschaltet ist und der Teilung des Spread-Spektrums-Signals in ein analoges Signal, welches sich in Phase befindet, und ein analoges Signal, welches um 90 Grad phasenverschoben ist, dient;
  - 35 - Konvertereinrichtungen (222, 224), die mit der Phasenteilereinrichtung verbunden sind und der Umwandlung der analogen, in Phase befindlichen und um 90 Grad phasenverschobenen Signale in digitale, in Phase befindliche und um 90 Grad phasenverschobene Signale bei variabler Wandlungsrate dient;
  - 40 - eine Verbindungseinrichtung, die mit einem Ausgang der Konvertereinrichtungen (222, 224) verbunden ist und dem kombinierten Bereitstellen der digitalen, in Phase und um 90 Grad phasenverschobenen Signale auf eine einzige Datenleitung zur seriellen Übertragung an andere Komponenten innerhalb des Demodulators (200) dient;
  - eine Steuer-Chip-Bezugseinrichtung (240) zur Erzeugung einer lokalen Bit-Sequenz, die einer vorbestimmten Steuer-Chip-Sequenz entspricht, die in vom Demodulator (200) empfangene Kommunikationssignale eingebettet übertragen wird, wobei die lokale Bit-Sequenz mit einer vorbestimmten Periode erzeugt wird;
  - 45 - eine Trägerschwingungs-Nachführeinrichtung (280), die mit der Kombiniereinrichtung und der Steuer-Bezugseinrichtung (240) verbunden ist, um die lokale Steuer-Chip-Sequenz in einer zeitlich festgelegten Beziehung mit den empfangenen Signalen zu vergleichen, um die Zeitsteuerung der Code-Teilungs-Spread-Spektrum-Kommunikationssignale mit Bezug auf die lokale Steuer-Chip-Sequenz zu bestimmen und um die Frequenz der variablen Frequenzquelle (210) einzustellen;
  - 50 - eine Chip-Zeit-Nachführungseinrichtung, die mit der Kombiniereinrichtung und der Steuer-Bezugseinrichtung (240) verbunden ist, um die lokale Steuer-Chip-Sequenz mit den empfangenen Signalen in einer Vielzahl von zeitlich festgelegten Beziehungen zu vergleichen, um die Zeitsteuerung der Code-Teilungs-Spread-Spektrum-Kommunikationssignale mit Bezug auf die lokale Steuer-Chip-Sequenz zu bestimmen und um die Wandlungsrate für die Konvertereinrichtung einzustellen;
  - 55 - Baugruppen-Chip-Einrichtung (250) zur Erzeugung einer der zugewiesenen Ausbreitungsfunktion

entsprechenden Bit-Sequenz;

- eine Despredding-Einrichtung (252), die mit der Kombiniereinrichtung und der Baugruppen-Chip-Einrichtung verbunden ist, um in Phase befindliche und um 90 Grad phasenverschobene Despredd-Spektrums-Informationssignale zu erzeugen;
- eine Ausgangseinrichtung (290), die mit der Despredding-Einrichtung (252) verbunden ist, um die in Phase befindlichen und die um 90 Grad phasenverschobenen Signale des Despredd-Spektrums in einem Ausgangs-Informationssignal zu kombinieren.

19. System nach Anspruch 18, dadurch gekennzeichnet, daß die Trägerschwingungs-Nachführeinrichtung (280) und die Chip-Zeit-Nachführeinrichtung ferner folgendes enthalten:

- eine erste, mit der Kombiniereinrichtung und der Steuer-Referenzeinrichtung (240) verbundene Korrelationseinrichtung (242) zum Vergleichen der digitalen, in Phase befindlichen und um 90 Grad phasenverschobenen Signale mit der Steuer-Chip-Sequenz und zum Bereitstellen einer Ausgangsrepräsentante eines ersten Korrelationsmusters;
- eine zweite, mit der Kombiniereinrichtung und der Steuer-Referenz-Einrichtung (240) verbundene Korrelationseinrichtung (244) zum Verzögern der digitalen, in Phase befindlichen und um 90 Grad phasenverschobenen Signale um einen Zeitbetrag von der Ordnung der halben Steuer-Chip-Periode und zum Vergleichen der digitalen, in Phase befindlichen und um 90 Grad phasenverschobenen Signale mit der Steuer-Chip-Sequenz und zum Bereitstellen einer Ausgangsrepräsentante eines zweiten Korrelationsmusters;
- eine dritte, mit der Kombiniereinrichtung und der Steuer-Referenz-Einrichtung (240) verbundene Korrelationseinrichtung (246) zur Verzögerung der digitalen, in Phase befindlichen und um 90 Grad phasenverschobenen Signale um einen Zeitbetrag von der Ordnung der Steuer-Chip-Periode und zum Vergleichen der digitalen, in Phase befindlichen und um 90 Grad phasenverschobenen Signale mit der Steuer-Chip-Sequenz und zum Bereitstellen einer Ausgangsrepräsentante eines dritten Korrelationsmusters;
- mit der ersten und der dritten Korrelationseinrichtung verbundene Chip-Synchronisations-Einrichtungen (270, 274) zum Einstellen der Wandlungsrate der Konvertereinrichtung in Abhängigkeit vom Ausgangssignal der ersten und dritten Korrelationseinrichtung und
- einen mit der zweiten Korrelationseinrichtung (244) verbundenen Trägerfrequenz-Nachführungs-Regelkreis (280) zum Einstellen der variablen Frequenzquelle in Abhängigkeit vom Ausgangssignal der zweiten Korrelationseinrichtung (244).

20. System nach Anspruch 18, ferner gekennzeichnet durch einen variablen Verstärkungsregler (204), der zwischen die und in Reihe mit der Eingangseinrichtung (190) und mit dem Radiofrequenzmischer (208) geschaltet ist und eine automatische Verstärkungsregeleinrichtung (206) hat, die mit der Kombiniereinrichtung verbunden ist und der Änderung der Verstärkung des variablen Verstärkungsreglers (204) in Abhängigkeit von einem absoluten Amplitudenwert der in Phase befindlichen oder um 90 Grad phasenverschobenen Signale dient.

21. System nach Anspruch 18, dadurch gekennzeichnet, daß die Konvertereinrichtung (222, 224) eine erste analoge Umwandlungseinrichtung (222) zur Umwandlung des in Phase befindlichen Signals in ein digitales in Phase befindliches Signal und eine zweite analoge Umwandlungseinrichtung (224) zur Umwandlung des um 90 Grad phasenverschobenen Signals in ein digitales um 90 Grad phasenverschobenes Signal aufweist.

22. System nach Anspruch 19, dadurch gekennzeichnet, daß die erste Korrelationseinrichtung folgendes enthält:

- eine erste Einrichtung (242) zur Vielphasen-Mischung der digitalen in Phase befindlichen und um 90 Grad phasenverschobenen Signale mit der Steuer-Chip-Sequenz;
- eine mit der ersten Einrichtung zur Vielphasen-Mischung (242) verbundene erste Kohärent-Summattons-Einrichtung (260) zur kohärenten Bildung der Summe der digitalen in Phase befindlichen und um 90 Grad phasenverschobenen Signale über einen vorbestimmten Zeitbereich und
- eine erste Quadrat-Summattons-Einrichtung (230) zur Bildung der Summe der Quadrate der digitalen in Phase befindlichen und um 90 Grad phasenverschobenen Signale über einen vorbestimmten Zeitbereich.

23. System nach Anspruch 22, dadurch gekennzeichnet, daß die zweite Korrelationseinrichtung folgendes

enthält

- eine zweite Einrichtung (244) zur Vielphasen-Mischung der digitalen, in Phase befindlichen und um 90 Grad phasenverschobenen Signale mit der Steuer-Chip-Sequenz;
  - eine zwischen der Kombinier-Einrichtung und der zweiten Einrichtung (244) zur Vielphasen-Mischung positionierte erste Verzögerungseinrichtung (232) und
  - eine mit der zweiten Einrichtung (244) zur Vielphasen-Mischung verbundene zweite Kohärent-Summers-Einrichtung (262) zur kohärenten Bildung der Summe der digitalen in Phase befindlichen und um 90 Grad phasenverschobenen Signale über einen vorbestimmten Zeitbereich.
24. System nach Anspruch 23, dadurch gekennzeichnet, daß die dritte Korrelationseinrichtung folgendes enthält:
- eine dritte Einrichtung (246) zur Vielphasen-Mischung der digitalen in Phase befindlichen und um 90 Grad phasenverschobenen Signale mit der Steuer-Chip-Sequenz;
  - eine zweite zwischen der ersten Verzögerungseinheit (232) und der dritten Einheit (246) zur Vielphasen-Mischung positionierte Verzögerungseinheit (236);
  - eine dritte mit der dritten Einheit (246) zur Vielphasen-Mischung verbundene Kohärent-Summers-Einrichtung (264) zur kohärenten Bildung der Summe der digitalen in Phase befindlichen und um 90 Grad phasenverschobenen Signale über einen vorbestimmten Zeitbereich und
  - eine zweite Quadrat-Summers-Einrichtung (274) zur Bildung der Summe der Quadrate der digitalen, in Phase befindlichen und um 90 Grad phasenverschobenen Signale über einen vorbestimmten Zeitbereich.
25. Kommunikationssystem nach Anspruch 7, dadurch gekennzeichnet, daß die Empfangseinrichtung ferner einen Demodulator (200) aufweist, der folgendes enthält:
- eine Eingangseinrichtung (214) zum Abtasten der im wesentlichen gesamten Bandbreite des Code-Teilungs-Spread-Spektrum-Kommunikationssignals;
  - eine in Reihe mit der Eingangseinrichtung geschaltete Phasenteilereinrichtung zum Zerlegen des Spread-Spektrums-Signals in ein analoges in Phase befindliches Signal und ein analoges um 90 Grad phasenverschobenes Signal;
  - mit der Phasenteilereinrichtung verbundene Konvertereinrichtungen (222, 224) zur Umwandlung der analogen, in Phase befindlichen und um 90 Grad phasenverschobenen Signale in digitale, in Phase befindliche und um 90 Grad phasenverschobene Signale bei variabler Wandlungsgeschwindigkeit.
26. System nach Anspruch 1, dadurch gekennzeichnet, daß die Spread-Spektrum-Kommunikationssignale über mindestens einen Kommunikationskanal übertragen werden und daß die Trenneinrichtung eine Trennung zwischen Gleichkanal-Signalen im Bereich von ungefähr einem Dezibel bis 15 dB gewährleistet.
27. System nach Anspruch 1, dadurch gekennzeichnet, daß die Kommunikationseinrichtung so konfiguriert ist, daß die Möglichkeit der Informationssignalübertragung von mindestens einer zentralen Kommunikationsstation (16) an mindestens einen fernen Systembenutzer besteht.
28. System nach Anspruch 1, dadurch gekennzeichnet, daß die Kommunikationseinrichtung so konfiguriert ist, daß die Möglichkeit der Informationssignalübertragung von mindestens einem fernen Systembenutzer an mindestens eine zentrale Kommunikationsstation (16) besteht.
29. Verfahren zur Bereitstellung von Hochkapazitäts-Vielfachzugriffs-Kommunikationen für eine Vielzahl von Kommunikationsservice-Benutzern, welches die folgenden Schritte aufweist:
- Umwandlung einer Vielzahl von Schmalband-Eingangsinformationssignalen in eine Vielzahl von breitbandbenutzeradressierbaren Code-Teilungs-Spread-Spektrum-Kommunikationssignalen unter Benutzung einer zugewiesenen Ausbreitungsfunktion und einer vorbestimmten Trägerfrequenz und
  - Übertragung der Code-Teilungs-Spread-Spektrum-Kommunikationssignale zwischen den Benutzern,
- gekennzeichnet durch folgende Schritte:
- ungleiche Gewichtung der Signalleistung bei der Übertragung der Spread-Spektrum-Kommunikationssignale, wobei die an einen ausgewählten Empfangsbenutzer gerichteten Signale eine größere mittlere Signalstärke haben als die an andere Benutzer gerichteten Störsignale und
  - Umwandlung jedes empfangenen adressenrichtigen Code-Teilungs-Spread-Spektrum-Kommunikationssignals

tionssignals in ein entsprechendes Schmalband-Informationssignal.

30. Verfahren nach Anspruch 29, gekennzeichnet durch die Übermittlung einer Steuer-Chip-Sequenz, die aus einer vorbestimmten Sequenz von Daten-Bits besteht.
- 5 31. Verfahren nach Anspruch 29, dadurch gekennzeichnet, daß der Übertragungsschritt den Schritt der Umsetzung der Spread-Spektrum-Kommunikationssignale zwischen den Benutzern durch mindestens einen Umsetzer aufweist.
- 10 32. Verfahren nach Anspruch 31, dadurch gekennzeichnet, daß der Umsetzungsschritt die Schritte des Empfangens und des Aussendens der Spread-Spektrum-Kommunikationssignale durch mindestens einen erdgestützten Umsetzer (12) aufweist.
- 15 33. Verfahren nach Anspruch 31, dadurch gekennzeichnet, daß der Umsetzungsschritt die Schritte des Empfangens und des Sendens der Spread-Spektrum-Kommunikationssignale durch mindestens einen satellitengestützten Umsetzer (14) umfaßt.
- 20 34. Verfahren nach Anspruch 31, dadurch gekennzeichnet, daß der Umsetzungsschritt die Schritte des Empfangs und des Sendens der Spread-Spektrum-Kommunikationssignale durch mindestens einen erdgestützten Umsetzer (12) und mindestens einen satellitengestützten Umsetzer (14) aufweist.
- 25 35. Verfahren nach Anspruch 29, dadurch gekennzeichnet, daß der Schritt der ungleichen Signalleistungsgewichtung die Schritte des Empfangens oder des Sendens von Spread-Spektrum-Kommunikationssignalen über ein Antennenfeld (66, 92, 132), welches mehrfache verstellbare Strahlen erzeugt, aufweist.
- 30 36. Verfahren nach Anspruch 29, dadurch gekennzeichnet, daß der Schritt der ungleichen Signalleistungsgewichtung den Schritt der Erzeugung von Polarisationsmoden in einer Antenne (66, 92, 132) aufweist.
- 35 37. Verfahren nach Anspruch 29, dadurch gekennzeichnet, daß der Schritt der ungleichen Signalleistungsgewichtung den Schritt der Verringerung der Signalübertragungsleistung für einen Benutzer während Perioden geringer Eingangs-Informationssignal-Aktivität aufweist.
- 40 38. Verfahren nach Anspruch 29, dadurch gekennzeichnet, daß der Schritt der ungleichen Signalleistungsgewichtung den Schritt der Einstellung der einem Code-Teilungs-Spread-Spektrum-Kommunikationssignal zugeteilten Signalübertragungsleistung auf ein minimales zur Herstellung und Aufrechterhaltung einer Kommunikationsverbindung erforderliches Leistungsniveau aufweist.
- 45 39. Verfahren nach Anspruch 29, dadurch gekennzeichnet, daß der Schritt der ungleichen Signalleistungsgewichtung die Schritte des Sendens oder des Empfangens ein und desselben Code-Teilungs-Spread-Spektrum-Kommunikationssignals durch mindestens zwei voneinander räumlich getrennte Stationen aufweist, so daß Interferenzmuster erzeugt werden, die das Signal/Rausch-Verhältnis für die Code-Teilungs-Spread-Spektrum-Kommunikationssignale bei einem bestimmten Empfangsbenutzer maximieren.
- 50 40. System nach einem der Ansprüche 1 bis 28, dadurch gekennzeichnet, daß das System eine hohe System-Benutzerkapazität hat und eine Einrichtung aufweist zum Austausch von systembenutzeradressierbaren Informationssignalen zwischen mindestens zweien aus einer Vielzahl von Systembenutzern unter Benutzung adressentsprechender Code-Teilungs-Spread-Spektrum-Kommunikationssignale, wobei die Kommunikationseinrichtung eine gegenseitige Kommunikationsstörung in der Kommunikation zwischen den mindestens zwei Systembenutzern erzeugt durch gleichzeitigen Code-Teilungs-Spread-Spektrum-Kommunikationssignal-Austausch zwischen anderen Systembenutzern und wobei die Kommunikationseinrichtung eine Betriebsverstärkung zur Reduzierung der gegenseitigen Störung hat und das System ferner eine mit der Kommunikationseinrichtung verbundene Trenneinrichtung enthält zur Erhöhung der vom Systembenutzer empfangenen mittleren Signalleistung der systembenutzeradressierenden Code-Teilungs-Spread-Spektrum-Kommunikationssignale bei Signalaustausch zwischen den mindestens zwei Systembenutzern bezogen auf die Leistung des aus der gleichzeitigen Kommunikation zwischen den anderen Systembenutzern resultierenden gegenseitigen Störsignals.
- 55 41. System nach Anspruch 40, dadurch gekennzeichnet, daß die Trenneinrichtung ein Antennensystem (68) aufweist, welches ein Antennenstrahlmuster hat, das mehrfache, gerichtete Strahlen erzeugt.

42. System nach Anspruch 40, dadurch gekennzeichnet, daß die Trenneinrichtung ein Antennensystem (132) aufweist, welcher derart konfiguriert ist, daß es Polarisationsmodenauswahl zwischen einer Vielzahl von Polarisationsmoden gestattet.
- 5 43. System nach Anspruch 40, dadurch gekennzeichnet, daß die Trenneinrichtung folgendes aufweist:
- Aktivitätsmessungseinrichtung (324) zur Messung der Signalaktivitätspegel für die Informationssignale in bezug auf ein Nicht-Aktivitätsniveau über eine vorbestimmte Abtastzeit und zur Bereitstellung eines der gemessenen Aktivität entsprechenden Aktivitätssignals und
  - eine mit der Kommunikationseinrichtung verbundene Leistungs-Regeleinrichtung (318) zur Einstellung des Sendeleistungsspiels für die Spread-Spektrum-Kommunikationssignale in Abhängigkeit von Änderungen des Aktivitätssignals.
- 10
44. System nach Anspruch 40, dadurch gekennzeichnet, daß die Trenneinrichtung Interferenzmusteranordnungen aufweist zur Erzeugung von Interferenzmustern maximalen Signal/Rausch-Verhältnisses in den übertragenen Code-Teilungs-Spread-Spektrum-Kommunikationssignalen an einem Empfangsort, wobei die Interferenzmusteranordnungen (56, 86, 100, 166) Übertragungseinrichtungen zur Übertragung ein und desselben Kommunikationssignals über mindestens zwei verschiedene Kommunikationspfade zum Empfangsort und eine mit den Übertragungseinrichtungen verbundene Regeleinrichtung (44) zur Einstellung der Signalphase oder der Übertragungsbeginnzeitpunkte bei den Übertragungen ein und desselben über verschiedene Kommunikationspfade übertragenen Signals hat.
- 15
45. System nach Anspruch 40, dadurch gekennzeichnet, daß die Kommunikationseinrichtung ferner ein gleiches Kommunikationssignal über mindesten zwei verschiedene Kommunikationspfade überträgt und die Trenneinrichtung eine Signal-Kombiniereinrichtung aufweist zur kohärenten Verbindung des gleichen Kommunikationssignals, wie es an einem Empfangsort von den unterschiedlichen Kommunikationspfaden empfangen wurde, wobei die Signal-Kombiniereinrichtung eine Empfangseinrichtung zum Empfang der jeweiligen der gleichen Kommunikationssignale aufweist, wie sie über die jeweiligen der unterschiedlichen Kommunikationspfade übertragen wurden, und eine mit der Empfangseinrichtung verbundene Regeleinrichtung zur Einstellung der Signalphase oder der Zeitsteuerung bei den Empfängern des gleichen über die verschiedenen Kommunikationspfade übertragenen Kommunikationssignals.
- 20
46. System nach Anspruch 40, dadurch gekennzeichnet, daß die Kommunikationseinrichtung folgendes aufweist:
- eine Vielzahl von erdgestützten Umsetzereinrichtungen (12) zur Übertragung der Spread-Spektrum Kommunikationssignale;
  - eine Vielzahl von Sende/Empfangs-Einrichtungen, von denen jede zum Empfangen der Spread-Spektrum-Kommunikationssignale und zum Senden von systembenutzeradressierten Code-Teilungs-Spread-Spektrum-Kommunikationssignalen mit jeweils einem von bestimmten Systembenutzern verbunden ist;
  - eine Vielzahl von Umsetzereinrichtungen (12), die ferner zum Empfang der von den Sende/Empfangs-Einrichtungen ausgesandten Code-Teilungs-Spread-Spektrum-Kommunikationssignale dienen, und
- 25
- daß die Trenneinrichtung die Platzierung jeder Umsetzereinrichtung (12) an einer vorbestimmten Position in bezug zu jeder anderen Umsetzereinrichtung (12) aufweist und jede Umsetzereinrichtung (12) zur Kommunikation mit mindestens einem der bestimmten Systembenutzer innerhalb einer vorbestimmten jeweiligen geographischen Region die Code-Teilungs-Spread-Spektrum-Kommunikationssignale mit gegenseitiger Störsignalleistung resultierend aus dem Signalaustausch in angrenzenden geographischen Regionen und als Funktion des Abstandes von diesen Regionen abgeschwächt benutzt.
- 30
47. System nach Anspruch 40, dadurch gekennzeichnet, daß die Kommunikationseinrichtung ferner folgendes aufweist:
- eine Verbindungs-Regeleinrichtung (320) zur Bestimmung eines minimal erforderlichen Leistungspegels zur Aufrechterhaltung von Code-Teilungs-Spread-Spektrum-Kommunikationssignalen in einer Benutzer-Kommunikationsverbindung über einem vorbestimmten Einfall-Leistungspegel und zur Bereitstellung eines diesem minimalen Leistungspegel entsprechenden Verbindungs-Regel-Signals;
  - eine mit der Kommunikationseinrichtung und mit der Verbindungs-Regeleinrichtung verbundene Leistungs-Regeleinrichtung (318) zur Einstellung eines Übertragungs-Leistungspegels für die Co-
- 35
- 40
- 45
- 50
- 55

de-Teilungs-Spread-Spektrum-Kommunikationssignale in Abhängigkeit vom Verbindungs-Regelsignal.

48. System nach Anspruch 40, dadurch gekennzeichnet, daß die Kommunikationseinrichtung ferner folgendes aufweist:
- Chipeinrichtungen (240, 308) zur Erzeugung einer Vielzahl quasi-orthogonaler Ausbreitungsfunktionen;
  - Code-Auswahl-Einrichtung zur Zuweisung einer dieser Ausbreitungsfunktionen an einen Benutzer;
  - eine Vielzahl mobiler Benutzerterminals (20, 22), die in der Lage sind, die Spread-Spektrum-Kommunikationssignale zu senden und zu empfangen, wobei jedes dieser Benutzerterminals (20, 22) folgendes aufweist:
    - Sende-einrichtungen (56, 86, 100, 166) zur Erzeugung eines Code-Teilungs-Spread-Spektrum-Kommunikationssignals in Abhängigkeit von einem Eingangs-Informationssignal, entsprechend einer zugewiesenen Ausbreitungsfunktion;
    - Empfänger-einrichtungen (42, 44, 84) zur Erzeugung eines Ausgangs-Informationssignals durch Verarbeitung eines empfangenen Code-Teilungs-Spread-Spektrum-Kommunikationssignals entsprechend der zugewiesenen Ausbreitungsfunktion und
    - mindestens eine ungerichtete Rundstrahlantenne (66, 92, 132) zur Verbindung der Sende-einrichtungen und der Empfänger-einrichtungen; und
  - mindestens eine Umsetzeinrichtung (12, 14, 16) zum Empfang der Code-Teilungs-Spread-Spektrum-Kommunikationssignale von der Vielzahl der Benutzerterminals (20, 22) und zum Umsetzen der empfangenen Code-Teilungs-Spread-Spektrum-Kommunikationssignale in eine zur Übertragung an einen bestimmten Empfangsbenutzer geeigneten Form.
49. Verfahren nach einem der Ansprüche 29 bis 39 zur Bereitstellung einer hohen Systembenutzerkapazität in einem Spread-Spektrums-Vielfachzugriff-Kommunikationssystem, in welchem die Systembenutzer benutzeradressierbare Informationssignale austauschen, wobei sie adreßentsprechende Code-Teilungs-Spread-Spektrum-Kommunikationssignale benutzen, in denen, mit Bezug auf Kommunikationen zwischen mindestens zwei Systembenutzern, andere Systembenutzer gegenseitige Störungen durch gleichzeitigen Austausch von Code-Teilungs-Spread-Spektrum-Kommunikationssignalen erzeugen, wobei das System eine Betriebsverstärkung zur Reduzierung der gegenseitigen Störung hat und das Verfahren ferner die gegenseitige Störung beim Signalaustausch zwischen den mindestens zwei Systembenutzern reduziert und gekennzeichnet ist durch die folgenden Schritte:
- Bereitstellung einer Vielzahl von systembenutzeradressierbaren Schmalband-Informationssignalen;
  - Umwandlung der Vielzahl der Systembenutzeradressierbaren Schmalband-Informationssignale in eine entsprechende Vielzahl von systembenutzeradreßentsprechenden Breitband-Code-Teilungs-Spread-Spektrum-Kommunikationssignale;
  - Übertragung der Vielzahl der Code-Teilungs-Spread-Spektrum-Kommunikationssignale zwischen den Systembenutzern;
  - Empfang der systembenutzeradreßentsprechenden Code-Teilungs-Spread-Spektrum-Kommunikationssignale bei jedem jeweiligen Systembenutzer und Empfang anderer, jeweiliger systembenutzeradreßentsprechender Code-Teilungs-Spread-Spektrum-Kommunikationssignale als gegenseitige Störung;
  - für jeden jeweiligen Systembenutzer Erzeugung eines Anstieges der vom Systembenutzer empfangenen mittleren Signalleistung der systembenutzeradreßentsprechenden Code-Teilungs-Spread-Spektrum-Kommunikationssignale in bezug auf die gegenseitige Störsignalleistung der anderen systembenutzeradreßentsprechenden Code-Teilungs-Spread-Spektrum-Kommunikationssignale und
  - bei jedem jeweiligen Systembenutzer Umwandlung der empfangenen adreßentsprechenden Code-Teilungs-Spread-Spektrum-Kommunikationssignale in entsprechende benutzeradressierbare Informationssignale.
50. Verfahren nach Anspruch 49, dadurch gekennzeichnet, daß der Schritt der Erzeugung eines Anstieges der Signalleistung folgende Schritte aufweist:
- Bereitstellung eines Antennensystems (68) mit einem Antennenstrahlmuster, das vielfache, gerichtete Strahlen erzeugt, wobei jeder Strahl bestimmten Systembenutzern entspricht und
  - Abstrahlung der jeweiligen systembenutzeradreßentsprechenden Code-Teilungs-Spread-Spektrum-Kommunikationssignale auf den jeweiligen Strahlen, die den jeweiligen Systembenutzern ent-



sprechen, welchen das abgestrahlte systembenutzeradreßentsprechende Kommunikationssignal entspricht.

51. Verfahren nach Anspruch 49, dadurch gekennzeichnet, daß der Schritt der Erzeugung eines Anstiegs der Signalleistung folgende Schritte aufweist:
  - Bereitstellung eines Antennensystems (68) mit einem Antennenstrahlmuster, das vielfache, gerichtete Strahlen erzeugt, wobei jeder Strahl bestimmten Systembenutzern entspricht und
  - auf jedem Strahl Sammlung von Code-Teilungs-Spread-Spektrum-Kommunikationssignalen von den entsprechenden Systembenutzern, die den jeweiligen Strahlen entsprechen.
52. Verfahren nach Anspruch 49, dadurch gekennzeichnet, daß der Schritt der Erzeugung eines Anstiegs der Signalleistung folgenden Schritt aufweist: Versorgung jedes Systembenutzers mit einem polarisationsmodenselektierbaren Antennensatz zum Empfang ausgesandter Code-Teilungs-Spread-Spektrum-Kommunikationssignale entsprechend einem vorbestimmten Polarisationsmodus aus einer Vielzahl von Polarisationsmoden, wo adreßentsprechende Code-Teilungs-Spread-Spektrum-Kommunikationssignale entsprechend einem Polarisationsmodus übertragen werden, auf deren Empfang das Antennensystem jedes adreßentsprechenden Systembenutzers abgestimmt ist.
53. Verfahren nach Anspruch 49, dadurch gekennzeichnet, daß der Schritt der Erzeugung eines Anstiegs der Signalleistung folgende Schritte aufweist:
  - Messung der Signalaktivitätspegel für die Informationssignale in bezug auf ein Nicht-Aktivitätsniveau einer vorbestimmten Abtastzeit;
  - Bereitstellung eines den gemessenen Aktivitätspegeln entsprechenden Aktivitätssignals und
  - Einstellung des Sendeleistungsspiels für die Spread-Spektrum-Kommunikationssignale in Abhängigkeit von Änderungen im Aktivitätssignal.
54. Verfahren nach Anspruch 49, dadurch gekennzeichnet, daß der Schritt der Erzeugung eines Anstiegs der Signalleistung folgende Schritte aufweist:
  - beim Sendeschritt Übertragung eines gleichen systembenutzeradreßentsprechenden Code-Teilungs-Spread-Spektrum-Kommunikationssignals über mindestens zwei verschiedene Kommunikationspfade an einen adreßentsprechenden Systembenutzer, der sich an einem Empfangsort befindet und
  - Einstellung entweder der Signalphase oder der Signalübertragungs-Verzögerungszeit bei der Übertragung des gleichen, über die verschiedenen Kommunikationspfade übertragenen Kommunikationssignals, wobei ein Interferenzmuster vorkommt, welches ein maximales Signal/Rausch-Verhältnis in den gleichen übertragenen Kommunikationssignalen am Empfangsort hat.
55. Verfahren nach Anspruch 49, dadurch gekennzeichnet, daß der Schritt der Erzeugung eines Anstiegs der Signalleistung folgende Schritte aufweist:
  - Empfang eines gleichen, über mindestens zwei verschiedenen Kommunikationspfade im Übertragungsschritt übertragenen systembenutzeradreßentsprechenden Code-Teilungs-Spread-Spektrum-Kommunikationssignals bei einem Systembenutzer, der sich an einem Empfangsort befindet, und
  - kohärente Kombination des gleichen Kommunikationssignals, wie es auf den verschiedenen Kommunikationspfaden empfangen wurde durch Einstellung entweder der Signalphase oder der Signalempfangs-Verzögerungszeit, oder beider, des gleichen Kommunikationssignals, wie es auf den verschiedenen Kommunikationspfaden empfangen wurde.
56. Verfahren nach Anspruch 49, dadurch gekennzeichnet, daß der Übertragungsschritt folgende Schritte aufweist:
  - Bereitstellung einer Vielzahl von erdgestützten Umsetzern (12), wobei jeder zur Übertragung der Spread-Spektrum-Kommunikationssignale in der Lage ist;
  - Bereitstellung einer Sende/Empfangs-Einrichtung für bestimmte Systembenutzer, die in der Lage ist, die Spread-Spektrum-Kommunikationssignale zu senden und zu empfangen, unddaß der Schritt der Erzeugung eines Anstiegs der Signalleistung folgenden Schritt aufweist: Platzierung jedes Umsetzers (12) in einer vorbestimmten Position in bezug auf andere Umsetzer (12), wobei jeder Umsetzer (12) mit mindestens einem der bestimmten Systembenutzer innerhalb einer vorbestimmten jeweiligen geographischen Region unter Benutzung der Spread-Spektrum-Kommunikationssignale kommuniziert, wobei die gegenseitige Störsignalleistung von Kommunikationsverbindungen in angren-

zenden geographischen Regionen als Funktion des Abstandes von diesen gedämpft wird.

57. Verfahren nach Anspruch 49, ferner gekennzeichnet durch:

- 5 - Bestimmung eines minimalen Leistungspegels, der notwendig ist, um systembenutzeradreßentsprechende Code-Teilungs-Spread-Spektrum-Kommunikationssignale in einer Systembenutzer-Kommunikationsverbindung über einem vorbestimmten Einfalls-Leistungspegel aufrechtzuerhalten;
- Bereitstellung eines diesem bestimmten minimalen Leistungspegel entsprechenden Verbindungs-Regelungssignals und
- 10 - Einstellung des Übertragungs-Leistungspegels für die systembenutzeradreßentsprechenden Code-Teilungs-Spread-Spektrum-Kommunikationssignale in Abhängigkeit von dem Verbindungs-Regelungssignal.

15 **Revendications**

1. Un système de communication à accès multiple et à étalement de spectre (10, 30) comprenant des moyens de communication de signaux d'information entre au moins deux d'entre une pluralité d'utilisateurs du système (20, 22, 24, 26), utilisant des signaux de communication à spectre étalé et à répartition de codes, caractérisé par des moyens d'isolation couplés aux moyens de communication, pour pondérer de façon inégale la puissance de signal des signaux de communication à spectre étalé.
2. Un système selon la revendication 1, caractérisé en ce que les moyens d'isolation comprennent une antenne-réseau à commande de phase (68) couplée aux moyens de communication, pour générer des faisceaux multiples et orientables sensiblement simultanés.
- 25 3. Un système selon la revendication 1, caractérisé en ce que les moyens d'isolation comprennent une structure d'antenne (132) configurée pour obtenir une sélection de mode de polarisation parmi une pluralité de modes de polarisation.
- 30 4. Un système selon la revendication 1, caractérisé en ce que les moyens d'isolation comprennent des moyens de commande de puissance (270, 284, 318) pour faire varier le rapport cyclique d'une puissance de sortie pour les signaux de communication à spectre étalé en réponse à un niveau d'activité des signaux d'information.
- 35 5. Un système selon la revendication 1, caractérisé en ce que les moyens d'isolation comprennent des moyens de transmission (56, 86, 100, 166) pour émettre chacun des signaux de communication du spectre à partir d'au moins deux positions espacées l'une de l'autre (20, 22, 24, 26), les émissions des positions espacées l'une de l'autre présentant un rapport de phase et de temps permettant de générer des séquences d'interférence présentant un rapport signal/bruit maximal pour les signaux de communication à spectre étalé en une position de réception.
- 40 6. Un système selon la revendication 1, caractérisé en ce que les moyens d'isolation comprennent des moyens de commande de puissance (274) pour faire varier un niveau de puissance de sortie pour lesdits signaux de communication à spectre étalé en réponse à un niveau de puissance minimal nécessaire pour réaliser une liaison de communication.
- 45 7. Un système selon la revendication 1, caractérisé en ce que les moyens de communication comprennent en outre:
  - des moyens de génération d'une séquence de bits ("chip") (240, 308) pour générer une pluralité
  - 50 de fonctions d'étalement quasi-orthogonales;
  - des moyens de sélection de code pour affecter l'une des fonctions d'étalement à un utilisateur;
  - une pluralité de terminaux d'utilisateur mobiles (20, 22) capables d'émettre ou de recevoir les signaux de communication à spectre étalé, chacun desdits terminaux d'utilisateur (20, 22) comprenant:
  - des moyens d'émission (56, 86, 100, 166) pour générer un signal de communication à spec-
  - 55 tre étalé et à répartition de codes en réponse à un signal d'information reçu en entrée, selon une fonction d'étalement qui lui est affectée;
  - des moyens de réception (42, 44, 84) pour générer un signal d'information de sortie, grâce au traitement d'un signal de communication à spectre étalé et à répartition de codes, selon la fonction

d'étalement affectée et,

au moins une antenne omnidirectionnelle (66, 92, 132) couplée aux moyens d'émission (56, 86, 100, 166) et aux moyens de réception (42; 44; 84) et

au moins un moyen de répétition (12, 14, 60) pour recevoir des signaux de communication à spectre étalé et à répartition de codes provenant de la pluralité de terminaux utilisateurs (20, 22) et pour traduire les signaux de communication à spectre étalé et à répartition de code en une forme adéquate pour le transfert à un utilisateur destinataire prévu.

8. Un système selon la revendication 7, caractérisé en ce que le(s)dit(s) moyen(s) de répétition (12, 14, 20) comprennent en outre des moyens (240, 308) pour émettre une séquence de bits ("chlp") prédéterminée de pilotage vers lesdits utilisateurs.

9. Un système selon la revendication 7, caractérisé en ce que le(s)dit(s) moyen(s) de répétition (12, 14, 60) comprennent en outre un système d'antenne-réseau à commande de phase (68) capable de générer des faisceaux simultanés orientables.

10. Un système selon la revendication 7, caractérisé en ce que le(s)dit(s) moyen(s) de répétition comprennent au moins un moyen de répétition à base terrestre (12) situé au centre d'une zone géographique.

11. Un système selon la revendication 7, caractérisé en ce que le(s)dit(s) moyen(s) de répétition comprennent au moins un moyen de répétition à base satellitaire.

12. Un système selon la revendication 7, caractérisé en outre par au moins une station centrale de communication (16) pour recevoir des signaux de communication provenant dudit moyen de répétition (12, 14, 60) en vue de leur transfert vers un utilisateur destinataire prévu et pour émettre des signaux de communication vers le moyen de répétition (12, 14, 60) en vue de leur traduction et leur transfert vers un terminal d'utilisateur destinataire prévu (20, 22, 24, 26).

13. Un système selon la revendication 7, caractérisé en ce que les moyens de répétition (12, 14, 60) comprennent: au moins un répéteur à base terrestre (12) pour recevoir, traduire et réémettre les signaux de communication à spectre étalé; au moins un répéteur à base satellitaire (14) pour recevoir, traduire et réémettre les signaux de communication à spectre étalé; d'utilisateurs (20, 22, 24, 26) sont configurés pour émettre et recevoir des signaux de communication à spectre étalé à répartition de codes via l'un ou l'autre des répéteurs (12, 14), ledit répéteur étant configuré pour recevoir ou pour émettre des signaux de communication à spectre étalé et à répétition de codes vers ou en provenance des terminaux utilisateurs (20, 22, 24, 26).

14. Un système selon la revendication 7, caractérisé en ce que les moyens d'émission (324) comprennent en outre des moyens de détection d'activité pour capter les niveaux d'activité de signal dans ledit signal d'information d'entrée et pour faire diminuer le rapport cyclique de la puissance d'émission de terminal, en réponse à une diminution de l'activité captée en-dessous d'un niveau de seuil prédéterminé, pendant une durée prédéterminée d'échantillonnage.

15. Un système selon la revendication 8, caractérisé en ce que les moyens de répétition (12, 14, 60) comprennent en outre des moyens de détection d'activité (324) pour capter les niveaux d'activité dans les signaux de communication à spectre étalé et pour faire diminuer le rapport cyclique de puissance d'émission du répéteur en réponse à une diminution de l'activité captée en-dessous d'un niveau de seuil prédéterminé, pendant une durée prédéterminée d'échantillonnage.

16. Un système selon la revendication 7, caractérisé en ce que les moyens récepteurs comprennent en outre des moyens de réglage de puissance de liaison (318, 320) pour capter un niveau de puissance reçu dans des premiers signaux de communication à spectre étalé et à répartition de code, et pour régler la puissance appliquée à une antenne (66, 92, 132) pour émettre des deuxièmes signaux de communication à spectre étalé et à répartition de code en réponse au niveau de puissance détecté.

17. Un système selon la revendication 7, caractérisé en ce qu'il comprend des moyens de commande de polarisation (110) couplés à ladite antenne omnidirectionnelle (66, 92, 132) pour ajuster l'antenne de manière à sélectionner un mode de polarisation prédéterminé parmi une pluralité de modes de polarisation.

18. Le système de communication selon la revendication 7, caractérisé en ce que lesdits moyens de réception comprennent en outre un démodulateur (200) comprenant:

des moyens d'entrée pour recevoir des signaux de communication à spectre étalé et à répartition de codes;

5 une source à fréquence variable qui génère un signal de référence local d'une fréquence prédéterminée;

un mélangeur à fréquence radio (208) raccordée auxdits moyens d'entrée et à ladite source à fréquence variable (210) pour mélanger les signaux de communication à spectre étalé et à répartition de codes avec le signal de référence local, pour fournir un signal à spectre étalé intermédiaire;

10 des moyens de filtrage (214) raccordés en série avec ledit mélangeur à fréquence radio (208) pour éliminer des composants fréquentiels indésirables dudit signal à spectre étalé intermédiaire;

des moyens de division de phase (220) raccordés en série avec lesdits moyens de filtrage (214) pour diviser ledit signal à spectre étalé en un signal analogique en-phase et un signal analogique en quadrature;

15 des moyens convertisseurs (222, 224) raccordés auxdits moyens de division de phase, pour convertir lesdits signaux analogiques en-phase et en quadrature en des signaux numériques en-phase et en quadrature à un taux variable;

des moyens de combinaison raccordés à une sortie desdits moyens convertisseurs (224, 222) pour juxtaposer en séries ledit signaux numériques en-phase et en quadrature sur une ligne de données unique pour le transfert à d'autres composants dudit démodulateur (200);

20 des moyens de référence de génération d'une séquence de bits ("chip") de pilotage (240) pour générer une séquence locale de bit en correspondance avec une séquence prédéterminée de bits ("chip") de pilotage émise de façon contiguë avec les signaux de communication reçus par ledit démodulateur (200), ladite séquence locale de bits étant générée afin de présenter une période prédéterminée;

25 des moyens de poursuite de porteuse (280) raccordés auxdits moyens de combinaison et auxdits moyens de référence de pilotage (240) pour comparer ladite séquence de bits ("chip") locale de pilotage avec des signaux reçus selon une relation temporelle, pour déterminer la synchronisation temporelle desdits signaux de communication à spectre étalé et à répartition de codes, par rapport à ladite séquence de bits ("chip") locale de pilotage et pour régler la fréquence de ladite source fréquentielle (210);

30 des moyens de poursuite temporelle de ladite séquence de bits ("chip") raccordés auxdits moyens de combinaison et auxdits moyens de référence de pilotage (240) pour comparer ladite séquence de bits locale de pilotage avec les signaux reçus selon une pluralité de rapports temporels, afin de déterminer la synchronisation temporelle desdits signaux de communication à spectre étalé et à répartition de codes, par rapport à ladite séquence de bits locale de pilotage, et pour régler le taux desdits moyens convertisseurs;

35 des moyens de génération d'une séquence de bits ("chip") de l'unité (250) pour générer une séquence de bits qui corresponde à ladite fonction d'étalement affectée;

des moyens de désétalement (252) raccordés auxdits moyens de combinaison et auxdits moyens de génération de séquence de bits ("chips") de l'unité pour générer des signaux d'information en phase et en quadrature à spectre désétalement; et

40 des moyens de sortie (290) raccordés auxdits moyens de désétalement (252) pour combiner lesdits signaux en phase et en quadrature à spectre désétalement pour produire un signal d'information de sortie.

19. Le système selon la revendication 18, caractérisé en ce que lesdits moyens de poursuite de porteuse (280) et lesdits moyens de poursuite temporelle de la séquence de bits ("chip") comprennent en outre:

45 des premiers moyens de corrélation (242) raccordés auxdits moyens de combinaison et auxdits moyens de référence de pilotage (240) pour comparer lesdits signaux numériques en phase et en quadrature avec ladite séquence de bits ("chips") de pilotage et pour fournir un signal de sortie qui représente un premier motif de corrélation;

50 des deuxièmes moyens de corrélation (244) raccordés auxdits moyens de combinaison et auxdits moyens de référence de pilotage pour retarder pour une durée de l'ordre de la moitié de la durée de ladite séquence de bits ("chip") de pilotage lesdits signaux numériques en phase et en quadrature, et pour comparer lesdits signaux numériques en phase et en quadrature avec ladite séquence de bits ("chip") de pilotage et pour fournir un signal de sortie qui représente un deuxième motif de corrélation;

55 des troisièmes moyens de corrélation (246) raccordés auxdits moyens de combinaison et auxdits moyens de référence de pilotage (240) pour retarder pour une durée de l'ordre de la durée de ladite séquence de bits ("chip") lesdits signaux numériques en phase et en quadrature, et pour comparer lesdits signaux numériques en phase et en quadrature avec ladite séquence de bits ("chip") de pilotage et pour

fournir un signal de sortie qui représente un troisième motif de corrélation;

des moyens de synchronisation de la séquence de bits ("chip") (270, 274) raccordés auxdits premier et troisième moyens de corrélation pour faire varier le le taux desdits moyens de convertisseurs en réponse au signal de sortie fourni par lesdits premier et troisième moyens de corrélation; et

une boucle de poursuite de porteuse (280) raccordée auxdits deuxième moyens de corrélation (244) pour commander ladite source à fréquence variable en réponse au signal de sortie fourni par lesdits deuxième moyens de corrélation (244).

20. Le système selon la revendication 18, caractérisé en outre par un dispositif de commande à gain variable (204) disposé entre et raccordé en série avec lesdits moyens d'entrée (190) et ledit mélangeur à fréquence radio (208), ainsi que par des moyens de commande de gain automatiques (206) raccordés auxdits moyens de combinaison pour faire varier le gain dudit dispositif de commande à gain variable, en réponse à la valeur absolue de l'amplitude desdits signaux en phase et en quadrature.

21. Le système selon la revendication 18, caractérisé en ce que lesdits moyens convertisseurs (222, 224) comprennent des premiers moyens de conversion analogique (222) pour convertir ledit signal en-phase en un signal numérique en-phase et des deuxième moyens de conversion analogiques (224) pour convertir ledit signal en quadrature en un signal en quadrature numérique.

22. Le système selon la revendication 19, caractérisé en ce que lesdits premiers moyens de corrélation comprennent:

des premiers moyens (242) pour réaliser le mélange multiphase desdits signaux numériques en phase et en quadrature avec ladite séquence de bits ("chip") de pilotage;

des premiers moyens de sommation cohérente (260) couplés auxdits premiers moyens de mélange multiphase (242) pour générer la somme desdits signaux numériques en-phase et en quadrature, de façon cohérente sur une durée prédéterminée de temps; et

des premiers moyens de sommation des carrés (230) pour générer la somme des carrés desdits signaux numériques en-phase et en quadrature sur une durée prédéterminée de temps.

23. Le système selon la revendication 22, caractérisé en ce que lesdits deuxième moyens de corrélation comprennent:

des deuxième moyens (244) pour réaliser le mélange multiphase desdits signaux numériques en-phase et en quadrature avec ladite séquence de bits ("chip") de pilotage;

des premiers moyens de retard, positionnés entre lesdits premiers moyens de combinaison et lesdits deuxième moyens (244) pour réaliser le mélange multiphase; et

des deuxième moyens de sommation cohérente (262) couplés auxdits deuxième moyens (244) pour réaliser le mélange multiphase, pour générer la somme desdits signaux numériques en-phase et en quadrature de façon cohérente sur une durée prédéterminée de temps.

24. Système selon la revendication 23, caractérisé en ce que lesdits troisième moyens de corrélation comprennent:

des troisième moyens (246) pour réaliser le mélange multiphase desdits signaux numériques en-phase et en quadrature avec ladite séquence de bits ("chip") de pilotage;

des deuxième moyens de retard (236) positionnés entre lesdits premiers moyens de retard (232) et lesdits troisième moyens (246) pour réaliser le mélange multiphase;

des troisième moyens de sommation cohérente (264) couplés auxdits troisième moyens (246) pour réaliser le mélange multiphase, pour générer la somme desdits signaux numériques en phase et en quadrature de façon cohérente sur une durée prédéterminée de temps; et

des deuxième moyens de sommation des carrés (274) pour générer la somme des carrés desdits signaux numériques en phase et en quadrature sur une durée prédéterminée de temps.

25. Le système de communication selon la revendication 7, caractérisé en ce que lesdits moyens de réception comprennent en outre un démodulateur (200) comprenant:

des moyens d'entrée (214) pour échantillonner sensiblement toute la largeur de bande desdits signaux à spectre étalé et à répartition de codes;

des moyens de division de phase raccordés en série, avec lesdits moyens d'entrée, pour diviser lesdits signaux à spectre étalé en un signal analogique en-phase et un signal analogique en quadrature;

des moyens convertisseurs (222, 224) raccordés auxdits moyens de division de phase pour convertir lesdits signaux analogiques en-phase et en quadrature en des signaux numériques en-phase

et en quadrature, à un taux variable.

26. Système selon la revendication 1, caractérisé en ce que les signaux de communication à spectre étalé sont transférés sur au moins un canal de communication et en ce que les moyens d'isolation assurent un isolement entre les signaux du même canal, dans une gamme d'environ 1 dB à 15 dB.
27. Système selon la revendication 1, caractérisé en ce que les moyens de communication sont configurés en vue de communiquer des signaux d'information à partir d'au moins une station centrale de communication (16) vers au moins un utilisateur du système éloigné.
28. Système selon la revendication 1, caractérisé en ce que les moyens de communication sont configurés en vue de communiquer des signaux d'information à partir d'au moins un utilisateur du système éloigné, vers au moins une station centrale de communication (16).
29. Procédé permettant d'assurer des communications à accès multiple, à capacité élevée, vers une pluralité d'utilisateurs d'un service de communication, comprenant les étapes consistant à:
  - convertir une pluralité de signaux d'information d'entrée à bande étroite en une pluralité de signaux de communication à spectre étalé et à répartition de codes à large bande et susceptibles d'être adressés par un utilisateur, utilisant une fonction d'étalement qui y est affectée, et une fréquence porteuse prédéterminée; et
  - communiquer les signaux de communication à spectre étalé et à répartition de codes entre les utilisateurs; caractérisé par les étapes consistant à:
    - appliquer des pondérations inégales à la puissance de signal lors de la communication des signaux de communication à spectre étalé, les signaux dirigés vers un utilisateur-récepteur prédéterminé présentant une intensité de signal moyenne supérieure à celle des signaux d'interférence dirigés vers d'autres utilisateurs; et
    - convertir chaque signal de communication à spectre étalé et à répartition de codes reçu correspondant à une adresse reçue en un signal d'information correspondante à bande étroite.
30. Procédé selon la revendication 29, caractérisé par la communication d'une séquence de bits ("chip") de pilotage composée d'une séquence prédéterminée de bits de données.
31. Procédé selon la revendication 29, caractérisé en ce que ladite étape de communication comprend l'étape consistant à réaliser le relai des signaux de communication à spectre étalé entre des utilisateurs à travers au moins un répéteur.
32. Procédé selon la revendication 31, caractérisé en ce que l'étape consistant à relayer les signaux entre les utilisateurs comprend les étapes consistant à recevoir et à transmettre les signaux de communication à spectre étalé grâce à au moins un répéteur terrestre (12).
33. Procédé selon la revendication 31, caractérisé en ce que l'étape consistant à relayer les signaux entre les utilisateurs comprend les étapes consistant à recevoir et à émettre les signaux de communication à spectre étalé grâce à au moins un répéteur satellitaire (14).
34. Procédé selon la revendication 31, caractérisé en ce que l'étape consistant à relayer les signaux entre les utilisateurs comprend les étapes consistant à recevoir et à transmettre les signaux de communication à spectre étalé grâce à au moins un répéteur terrestre (12) et au moins un répéteur satellitaire (14).
35. Procédé selon la revendication 29, caractérisé en ce que l'étape consistant à affecter des pondérations inégales à la puissance de signal comprend les étapes consistant à recevoir ou à émettre des signaux de communication à spectre étalé au moyen d'une antenne-réseau (66, 92, 132) qui forme des faisceaux multiples orientables.
36. Procédé selon la revendication 29, caractérisé en ce que l'étape consistant à pondérer de façon inégale la puissance de signal comprend l'étape consistant à établir des modes de polarisation dans une antenne (66, 92, 132).
37. Procédé selon la revendication 29, caractérisé en ce que l'étape consistant à pondérer de façon inégale la puissance de signal comprend l'étape consistant à diminuer la puissance de signal d'émission pour un utilisateur pendant des périodes de faible activité du signal d'information d'entrée.

38. Procédé selon la revendication 29, caractérisé en ce que l'étape consistant à pondérer de façon inégale la puissance de signal comprend l'étape consistant à faire varier la puissance de signal d'émission appliquée à un signal de communication à spectre étalé et à répartition de codes pour arriver à un niveau de puissance minimale nécessaire pour établir et maintenir une liaison de communication (39).
- 5 39. Un procédé selon la revendication 29, caractérisé en ce que l'étape consistant à pondérer de façon inégale la puissance de signal comprend les étapes consistant à émettre ou à recevoir un même signal de communication à spectre étalé et à répartition de codes au moyen de au moins deux positions espacées l'une de l'autre, de façon à générer des modèles d'interférence, permettant d'optimiser un rapport signal/bruit pour les signaux de communication à spectre étalé et à répétition de code auprès d'un utilisateur destinataire prévu.
- 10 40. Système selon l'une quelconque des revendications 1 à 28, caractérisé en ce que le système présente une capacité élevée d'utilisateurs du système et comprend des moyens permettant de communiquer les signaux d'information adressables d'utilisateur du système entre au moins deux d'entre une pluralité d'utilisateurs du système en utilisant des signaux de communication à spectre étalé et à répartition de codes correspondant à des adresses, les moyens de communication étant susceptibles de générer une interférence mutuelle lors des communications entre lesdits au moins deux utilisateurs du système, grâce à la communication simultanée de signaux de communication à spectre étalé et à répartition de codes entre d'autres utilisateurs du système, les moyens de communication présentant un gain de traitement pour réduire l'interférence mutuelle; le système comprenant en outre des moyens d'isolation couplés aux moyens de communication, pour assurer, pour un utilisateur du système, une augmentation de la puissance moyenne des signaux de communication à spectre étalé et à répartition de codes correspondant à l'adresse de l'utilisateur du système pour des communications entre lesdits au moins deux utilisateurs du système, par rapport à la puissance du signal d'interférence mutuelle des communications simultanées entre les autres utilisateurs du système.
- 15 41. Système selon la revendication 40, caractérisé en ce que les moyens d'isolation comprennent un système d'antenne (68) présentant un diagramme d'antenne définissant des faisceaux directif multiples.
- 20 42. Système selon la revendication 40, caractérisé en ce que les moyens d'isolation comprennent un système d'antenne (132) configuré pour obtenir une sélection de modes de polarisation entre une pluralité de modes de pluralisation.
- 25 43. Système selon la revendication 40, caractérisé en ce que les moyens d'isolation comprennent:  
des moyens de détection d'activité (324) pour mesurer les niveaux d'activité de signal pour les signaux d'information, par rapport à un niveau correspondant à une activité zéro, sur une durée prédéterminée d'échantillonnage et pour fournir un signal d'activité qui correspond à l'activité mesurée; et  
des moyens de commande de puissance (318) couplés aux moyens de communication pour faire varier un rapport cyclique de transmission pour les signaux de communication à spectre étalé en réponse à des changements du signal d'activité.
- 30 44. Système selon la revendication 40, caractérisé en ce que les moyens d'isolation comprennent des moyens de génération de modèle d'interférence pour générer les modèles d'interférence présentant un rapport signal/bruit maximal à une position de réception pour des signaux de communication à spectre étalé et à répartition de code communiqués, les moyens de génération de modèles d'interférence (56, 86, 100, 166) présentant des moyens d'émission pour émettre un même signal de communication via au moins deux chemins de communication différents jusqu'à la position de réception et des moyens de commande (44) couplés aux moyens d'émission pour faire varier une phase de signal ou un instant de début d'émission dans les émissions du même signal de communication émis par les différents chemins de communication.
- 35 45. Système selon la revendication 40, caractérisé en ce que les moyens de communication réalisent en outre la communication d'un même signal de communication via au moins deux différents chemins de communication et en ce que les moyens d'isolation comprennent des moyens de combinaison de signal pour combiner de façon cohérente le même signal de communication tel que reçu à une position de réception sur les différents chemins de communication, les moyens de communication de signal présentant des moyens de réception pour recevoir chacun des mêmes signaux de communication tels que transmis via chacun des différents chemins de communication, et des moyens de commande couplés aux moyens de
- 40 45 50 55



réception pour faire varier la phase ou le positionnement temporel en réception du signal, lors des réceptions du même signal de communication via les différents chemins de communication.

- 5 46. Système selon la revendication 40, caractérisé en ce que les moyens de communication comprennent:  
une pluralité de moyens de répétition à base terrestre (12) pour émettre les signaux de communi-  
cation à spectre étalé;  
une pluralité de moyens de transmission/réception couplés chacun à l'un respectivement de cer-  
tains utilisateurs du système pour recevoir les signaux de communication à spectre étalé et pour émettre  
des signaux de communication à spectre étalé et répartition de codes, avec adressage pour un utilisateur  
10 du système;  
la pluralité de moyens de répétition, étant destinés en outre à recevoir des signaux de communi-  
cation à spectre étalé et à répartition de codes émis par les moyens de transmission/réception; et en ce  
que  
les moyens d'isolation comprennent le positionnement de chacun des moyens de répétition (12)  
15 à une position prédéterminée par rapport à chacun des autres moyens de répétition (12), chacun des  
moyens de répétition (12), lors des communications avec au moins un desdits certains utilisateurs du sys-  
tème à l'intérieur d'une zone géographique respective prédéterminée, utilisant les signaux de communi-  
cation à spectre étalé et à répétition de codes, la puissance de signal d'interférence mutuel provenant  
de communications à l'intérieur de zones géographiques adjacentes étant affaibli en fonction de leur dis-  
tance par rapport à ladite zone géographique prédéterminée.
- 20 47. Un système selon la revendication 40, caractérisé en ce que les moyens de communication comprennent  
en outre:  
des moyens de contrôle de liaison (320) pour détecter un niveau de puissance minimale nécessaire  
25 à maintenir des signaux de communication à spectre étalé et à répartition de codes, pour une liaison de  
communication d'utilisateur, à un niveau supérieur à un niveau de puissance incident prédéterminé, et  
pour générer un signal de contrôle de liaison en correspondance audit niveau minimal de puissance;  
des moyens de commande de puissance (318) raccordés aux moyens de communication et aux  
moyens de contrôle de liaison pour faire varier un niveau de puissance d'émission pour les signaux de  
communication à spectre étalé et à répartition de codes, en réponse au signal de contrôle de liaison.
- 30 48. Système selon la revendication 40, caractérisé en ce que les moyens de communication comprennent  
en outre:  
des moyens de génération de séquences de bits ("chip") (240, 308) pour générer une pluralité de  
fonctions d'étalement quasi-orthogonales;  
35 des moyens de sélection de codes pour affecter une fonction d'étalement à un utilisateur;  
une pluralité de terminaux d'utilisateurs mobiles (20, 22) capables d'émettre et de recevoir les si-  
gnaux de communication à spectre étalé, chacun des terminaux d'utilisateurs (20, 22) comprenant:  
des moyens d'émission (56, 86, 100, 166) pour générer, en fonction d'une fonction d'étalement af-  
fectée, un signal de communication à spectre étalé et à répartition de codes, en réponse à un signal d'in-  
formation d'entrée;  
40 des moyens de réception (42, 44, 84) pour générer un signal d'information de sortie par traitement  
d'un signal de communication à spectre étalé et à répartition de codes reçu, selon la fonction d'étalement  
affectée; et  
au moins une antenne omnidirectionnelle destinée à être couplée aux moyens d'émission et aux  
45 moyens de réception; et  
au moins un moyen de répétition (12, 14, 60) pour recevoir des signaux de communication à spectre  
étalé et à répétition de codes à partir de la pluralité de terminaux (20, 22) et pour traduire les signaux de  
communication à spectre étalé et à répartition de codes reçus sous une forme adéquate pour leur transfert  
à un utilisateur destinataire prévu.
- 50 49. Procédé selon l'une quelconque des revendications 29 à 39, permettant d'assurer une capacité élevée  
d'utilisateurs du système dans un système de communication à accès multiple par répartition de codes,  
dans lequel les utilisateurs du système réalisent la communication de signaux d'information adressables  
pour un utilisateur utilisant des signaux de communication à spectre étalé et à répartition de codes corres-  
pondant à des adresses, dans lequel, par rapport à des communications entre au moins deux utilisateurs  
55 du système, d'autres utilisateurs du système génèrent des interférences mutuelles en communiquant si-  
multanément des signaux de communication à spectre étalé et à répartition de codes, ledit système pré-

sentant un gain de traitement permettant de diminuer l'interférence mutuelle, ledit procédé permettant de diminuer encore l'interférence mutuelle pour les communications entre lesdits au moins deux utilisateurs du système et étant caractérisé par les étapes consistant à:

5 fournir une pluralité de signaux d'information à bande étroite adressables pour les utilisateurs du système;

convertir la pluralité de signaux d'information à bande étroite adressables pour les utilisateurs du système en une pluralité correspondante de signaux de communication à spectre étalé et à répartition de codes à large bande correspondant aux adresses d'utilisateurs du système;

10 émettre la pluralité de signaux de communication à spectre étalé et à répartition entre les utilisateurs du système;

recevoir au niveau de chaque utilisateur respectif du système, des signaux de communication à spectre étalé et à répartition de codes correspondant à l'adresse d'utilisateur du système et des signaux de communication à spectre étalé et à répartition de codes adressés à d'autres utilisateurs respectifs du système, en tant qu'interférence mutuelle ;

15 assurer pour chaque utilisateur respectif du système une augmentation de la puissance moyenne de signal réalisée pour l'utilisateur de système pour les signaux de communication à spectre étalé et à répartition de codes correspondant à l'adresse de l'utilisateur du système par rapport à la puissance de signal d'interférence mutuelle des autres signaux de communication à spectre étalé et à répétition de codes correspondant aux adresses d'autres utilisateurs du système; et

20 convertir, au niveau de chaque utilisateur respectif du système, les signaux de communication à spectre étalé et à répétition de codes reçus correspondant à l'adresse, en des signaux d'information susceptibles d'être adressés par un utilisateur.

50. Procédé selon la revendication 49, caractérisé en ce que l'étape consistant à assurer une augmentation de puissance de signal comprend les étapes consistant à:

fournir un système d'antenne (68) présentant un diagramme d'antenne comportant des faisceaux directifs multiples, chaque faisceau correspondant à certains utilisateurs du système; et

30 émettre chacun des signaux de communication à spectre étalé et à répétition de codes correspondant à une adresse d'utilisateur du système sur chacun des faisceaux correspondant à un utilisateur du système vers lequel est émis le signal de communication correspondant à l'adresse d'utilisateur du système.

51. Procédé selon la revendication 49, caractérisé en ce que l'étape consistant à assurer une augmentation de la puissance de signal comprend les étapes consistant à:

35 fournir un système d'antenne (68) présentant un diagramme d'antenne présentant des faisceaux directifs multiples, chacun des faisceaux correspondant à certains utilisateurs du système; et

collecter, à partir de chaque faisceau, des signaux de communication à spectre étalé et à répartition de codes provenant des utilisateurs du système, qui correspondent à chaque faisceau respectif.

40 52. Un procédé selon la revendication 49, caractérisé en ce que l'étape consistant à assurer une augmentation de la puissance de signal comprend l'étape consistant à fournir à chaque utilisateur du système une antenne avec sélection de mode de polarisation, conçue pour recevoir des signaux de communication selon un mode prédéterminé parmi une pluralité de modes de polarisation, des signaux de communication à spectre étalé et à division de codes correspondant à une adresse étant émise dans un mode de polarisation selon lequel le système d'antenne de chaque utilisateur du système correspondant à cette adresse est réglé en réception.

53. Procédé selon la revendication 49, caractérisé en ce que l'étape consistant à assurer une augmentation de la puissance de signal comprend les étapes consistant à:

50 mesurer des niveaux d'activité de signal pour les signaux d'information, par rapport à un niveau correspondant à une activité zéro, pendant une durée prédéterminée d'échantillonnage;

déterminer un signal d'activité qui corresponde aux niveaux d'activité mesurés;

faire varier un rapport cyclique de puissance d'émission pour les signaux de communication à spectre étalé, en fonction des changements du signal d'activité.

55 54. Un procédé selon la revendication 49, caractérisé en ce que l'étape consistant à assurer une augmentation de la puissance de signal comprend les étapes consistant à:

émettre, lors de l'étape d'émission, un même signal de communication à spectre étalé et à répartition

titution de codes correspondant à une adresse d'utilisateur du système via au moins deux différents chemins de communication vers un utilisateur du système correspondant à cette adresse, situé en une position de réception; et

5 faire varier, dans l'émission de ce même signal de communication, soit les phases du signal et soit le retard d'émission du signal tel qu'émis sur les différents chemins de communication, de sorte qu'il se produit un modèle d'interférence présentant un rapport signal/bruit maximal dans les mêmes signaux de communication émis, à la position de réception.

10 55. Un procédé selon la revendication 49, caractérisé en ce que ladite étape consistant à assurer une augmentation de la puissance de signal comprend les étapes consistant à:

recevoir, au niveau de l'utilisateur du système situé à une position de réception, un signal de communication à spectre étalé et à répartition de codes correspondant à une même adresse d'utilisateur du système, tel qu'émis sur au moins deux différents chemins de communication, lors de l'étape d'émission; et

15 combiner de façon cohérente le signal de communication tel que reçu sur les différents chemins de communication, par ajustement au moins de la phase de signaux et/ou du temps de retard de réception de ce même signal de communication tel que reçu via les différents chemins de communication.

20 56. Un procédé selon la revendication 49, caractérisé en ce que l'émission comprend les étapes consistant à:

fournir une pluralité de répéteurs à base terrestre (12) capable d'émettre chacun les signaux de communication à spectre étalé;

fournir, pour certains utilisateurs du système, un émetteur/récepteur capable d'émettre et de recevoir les signaux de communication à spectre étalé; et en ce que

25 l'étape consistant à assurer une augmentation de la puissance de signal comprend l'étape consistant à situer chaque répéteur (12) dans une position prédéterminée par rapport aux autres répéteurs (12), chaque répéteur, lors des communications avec au moins un desdits certains utilisateurs du système à l'intérieur d'une zone géographique respective prédéterminée, utilisant les signaux de communication à spectre étalé et à répétition de codes, la puissance de signal d'interférence mutuelle provenant de communications à l'intérieur de zones géographiques adjacentes étant affaibli en fonction de leur distance à ladite zone géographique prédéterminée.

30 57. Un procédé selon la revendication 49, caractérisé en outre par:

la détection d'un niveau minimal de puissance nécessaire pour maintenir des signaux de communication à spectre étalé et à répartition de codes correspondant à une adresse d'utilisateur du système, pour une liaison de communication d'utilisateur de système, au-dessus d'un niveau de puissance incidente prédéterminée.

l'utilisation d'un signal de contrôle de liaison correspondant au niveau minimal de puissance détecté; et

40 le réglage d'un niveau de puissance d'émission pour les signaux de communication à spectre étalé et à répétition de code, correspondant à une adresse d'utilisateur du système en fonction du signal de contrôle de liaison.

45

50

55

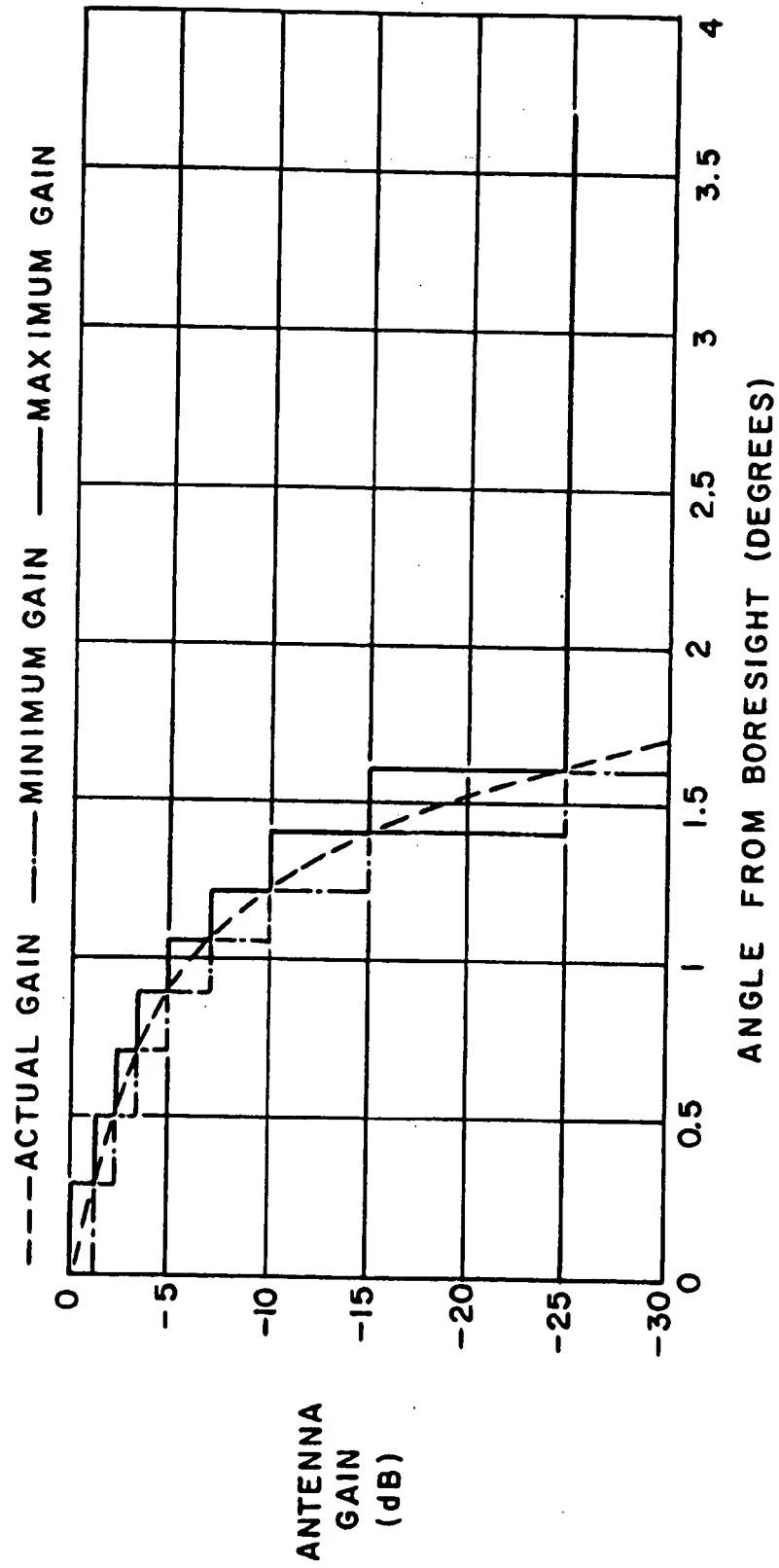


FIG. 1a

ANTENNA MARGINAL GAIN					
ATTN. RANGE (dB)	CUM. ANGLE (°)	$\Delta$ ANGLE (°)	# USERS (USERS)	WTD #USERS (USERS)	
0	1	0.6	189	188.59	
1	2	1.0	126	99.87	
2	3	1.4	126	79.33	
3	5	1.8	126	63.01	
5	7	2.1	94	29.82	
7	10	2.4	94	18.81	
10	15	2.8	126	12.57	
15	25	3.2	126	3.98	
25	$\infty$	7.4	1320	4.17	
TOTALS		7.4	2326	500.17	
FDMA REUSE FACTOR			CDMA REUSE FACTOR		
2.64			4.65		

FIG. 1b

RELATIVE CAPACITY INCREASE AND POLARIZATION ISOLATION vs. ELLIPTICITY			
ELLIPTICITY (dB)	AXIAL RATIO	CAPACITY INCREASE	POLARIZATION ISOLATION (dB)
0.00	1.00	100 %	$-\infty$
2.00	0.63	79 %	-18.81
4.00	0.40	63 %	-12.91
6.00	0.25	50 %	-9.57
8.00	0.16	40 %	-7.32
10.00	0.10	32 %	-5.69
12.00	0.06	25 %	-4.46
14.00	0.04	20 %	-3.51
16.00	0.03	16 %	-2.78
18.00	0.02	13 %	-2.20
20.00	0.01	10 %	-1.74

FIG. 14

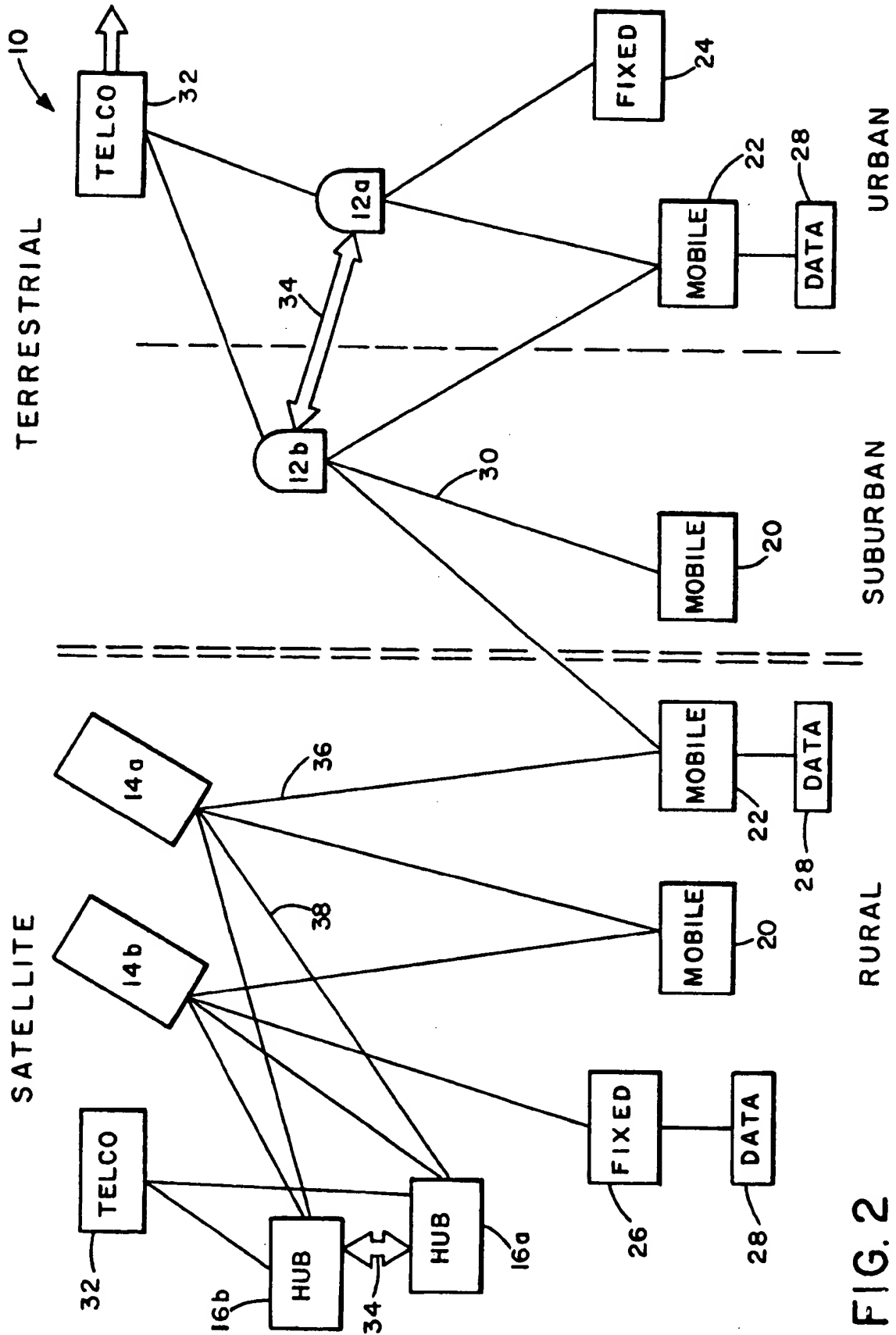


FIG. 2

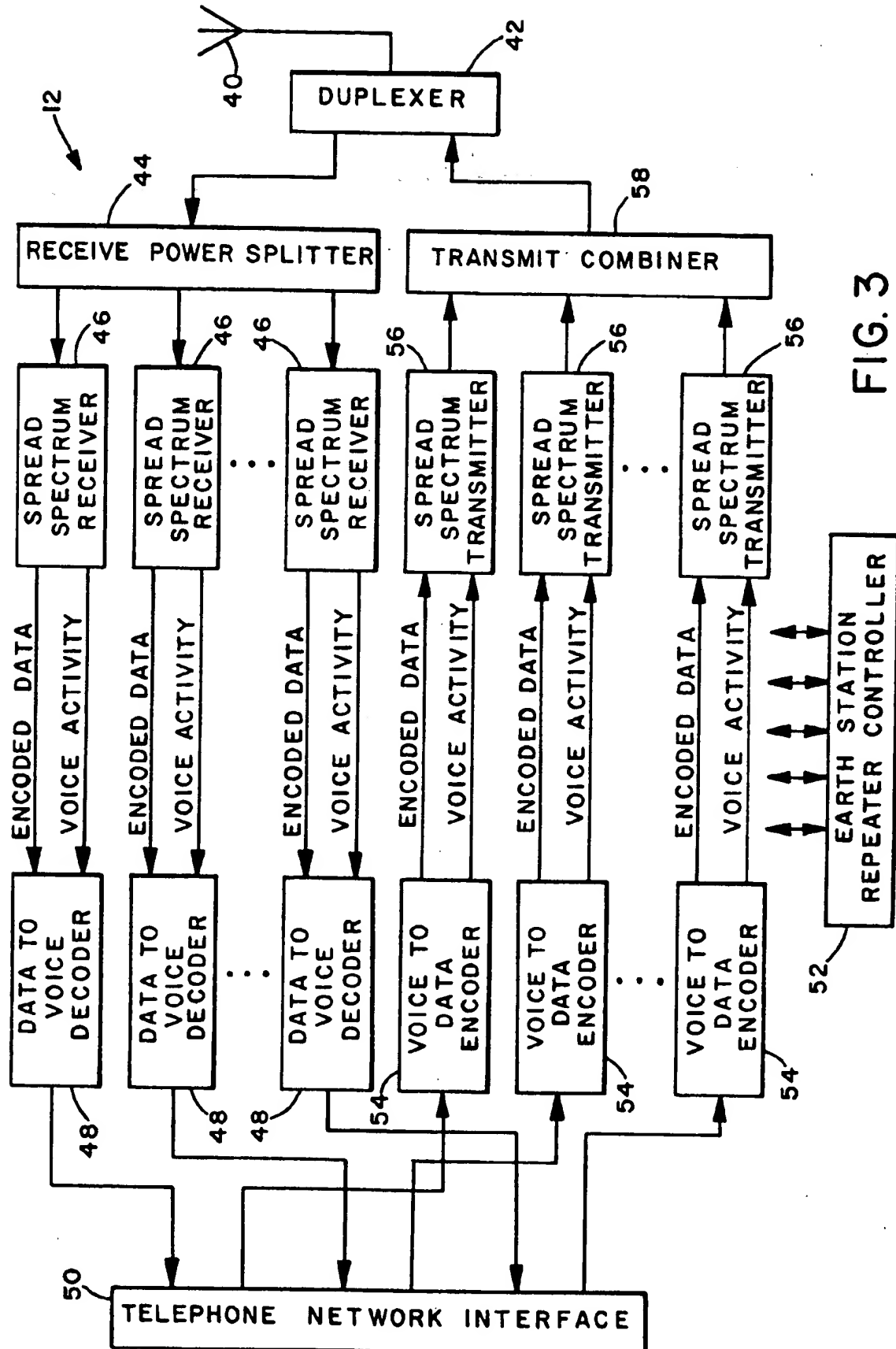


FIG. 3



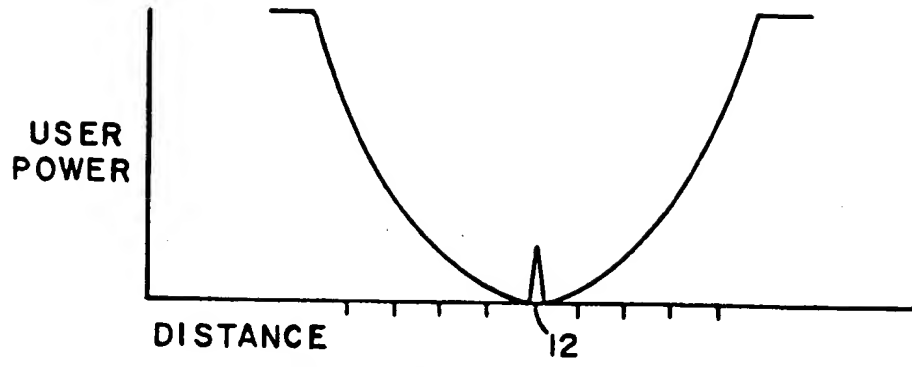


FIG. 4

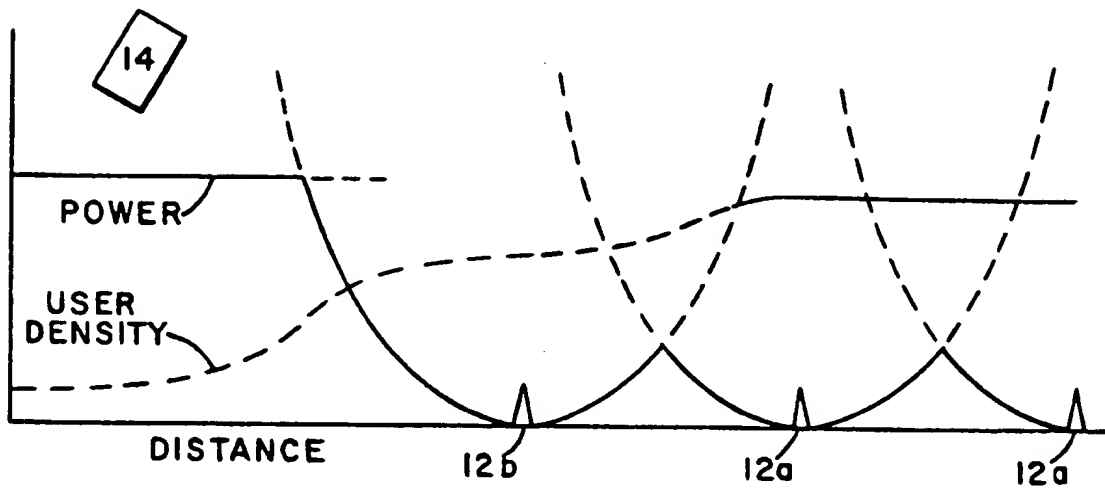


FIG. 6

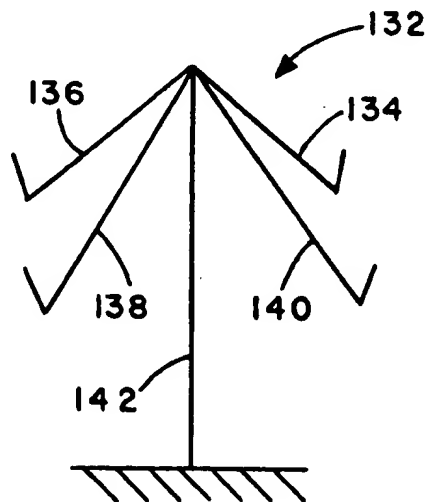


FIG. II

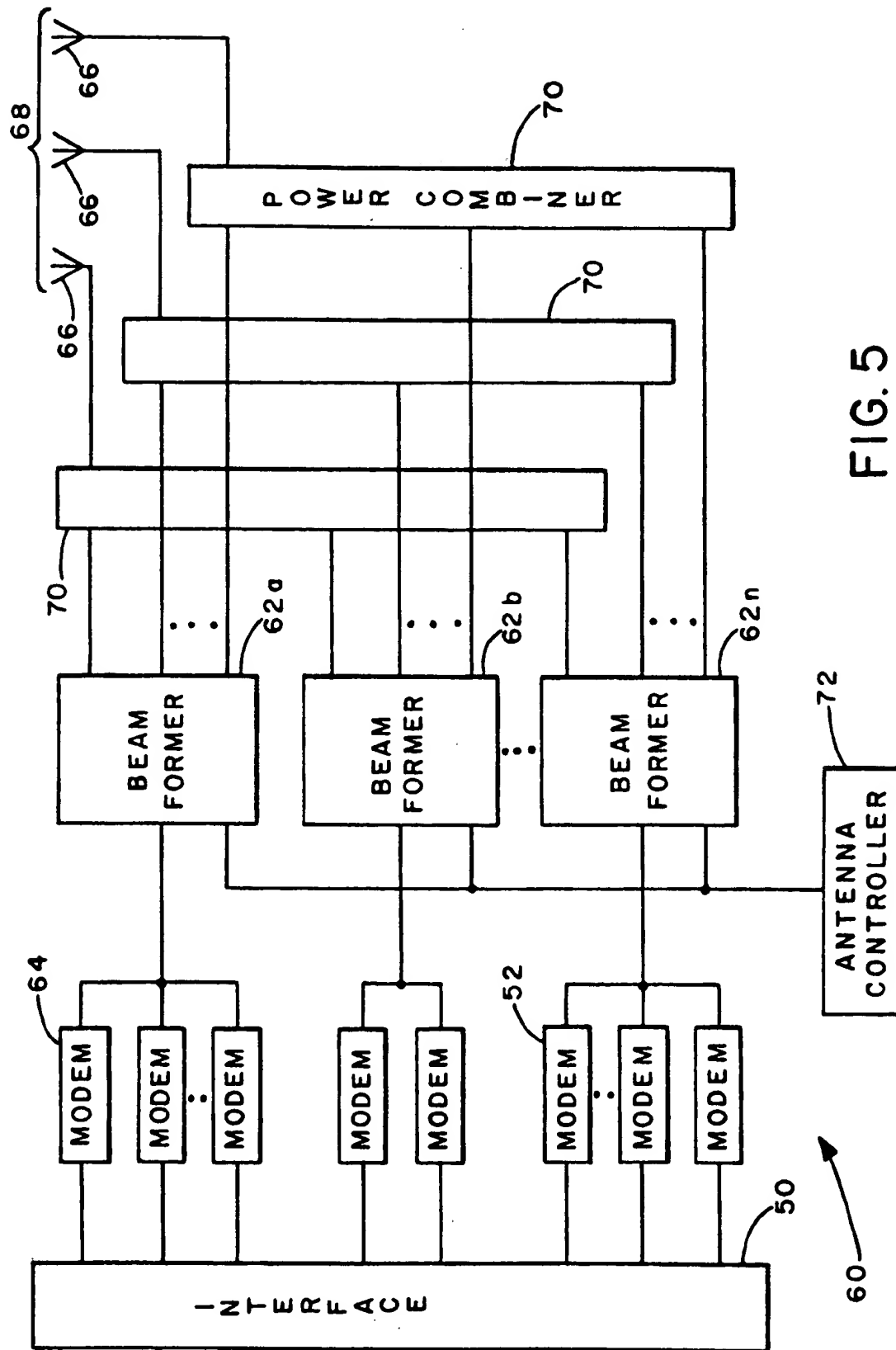


FIG. 5

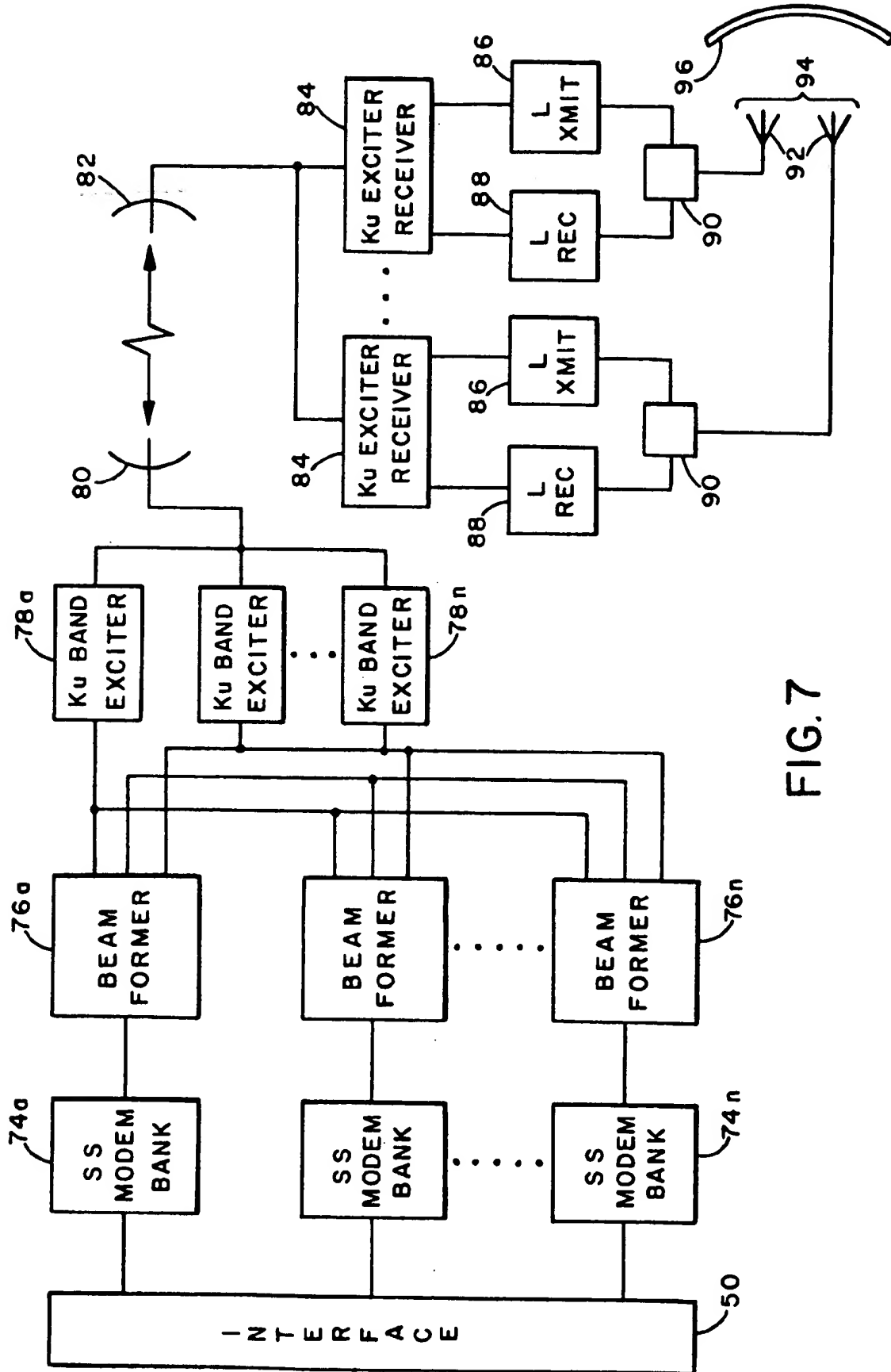


FIG. 7

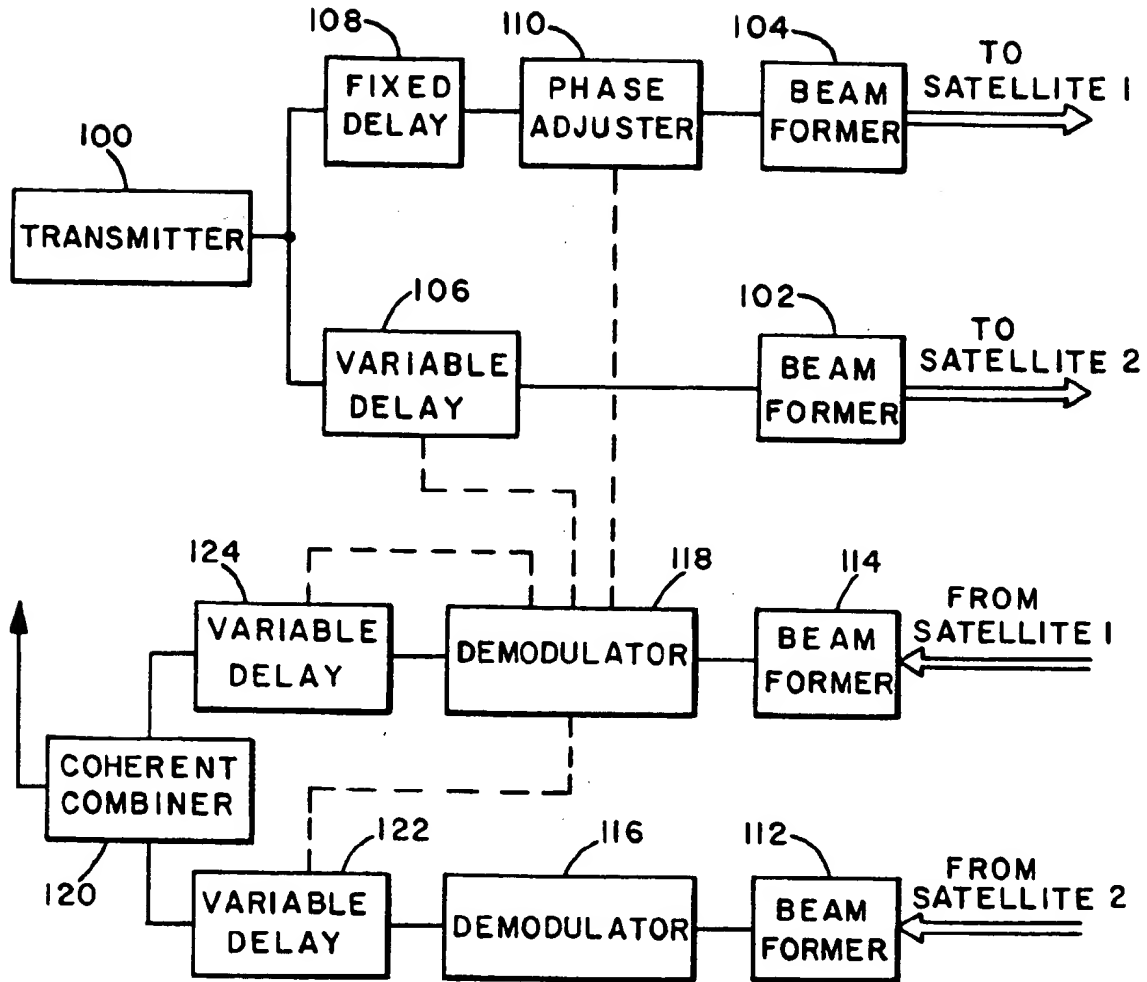


FIG. 9

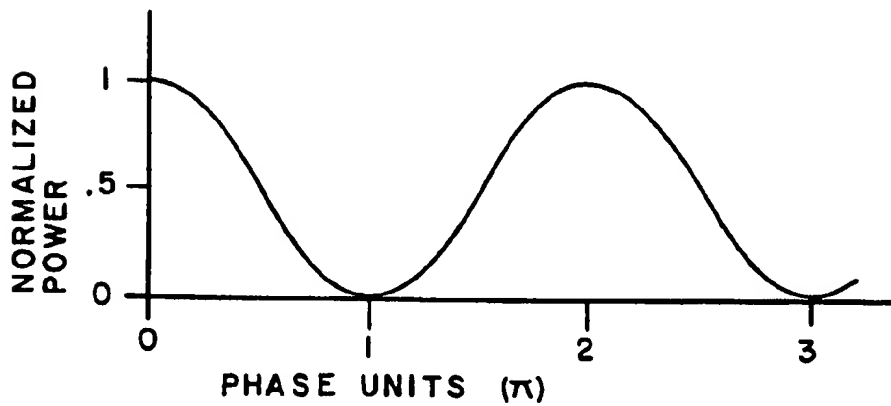


FIG. 8

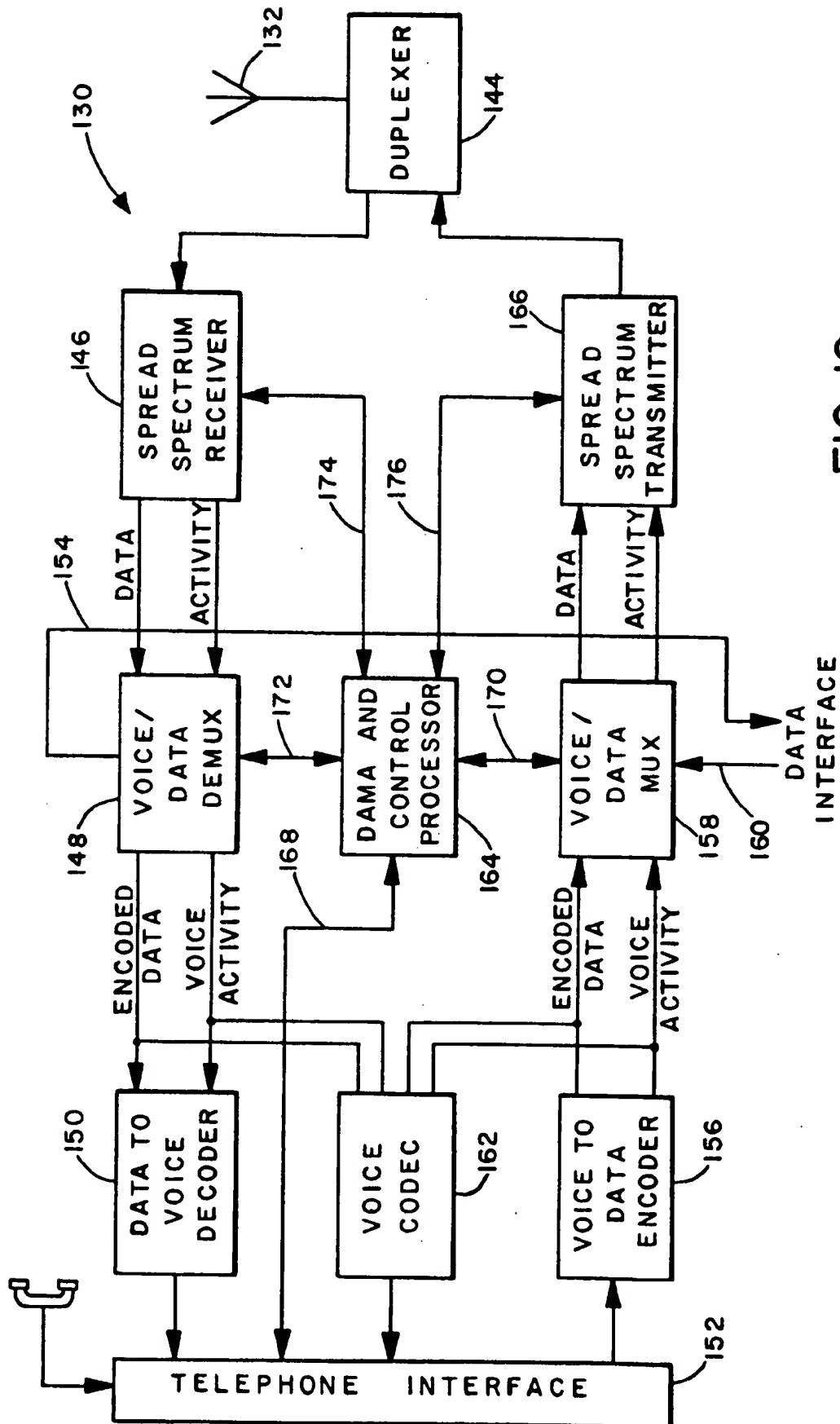


FIG. 10

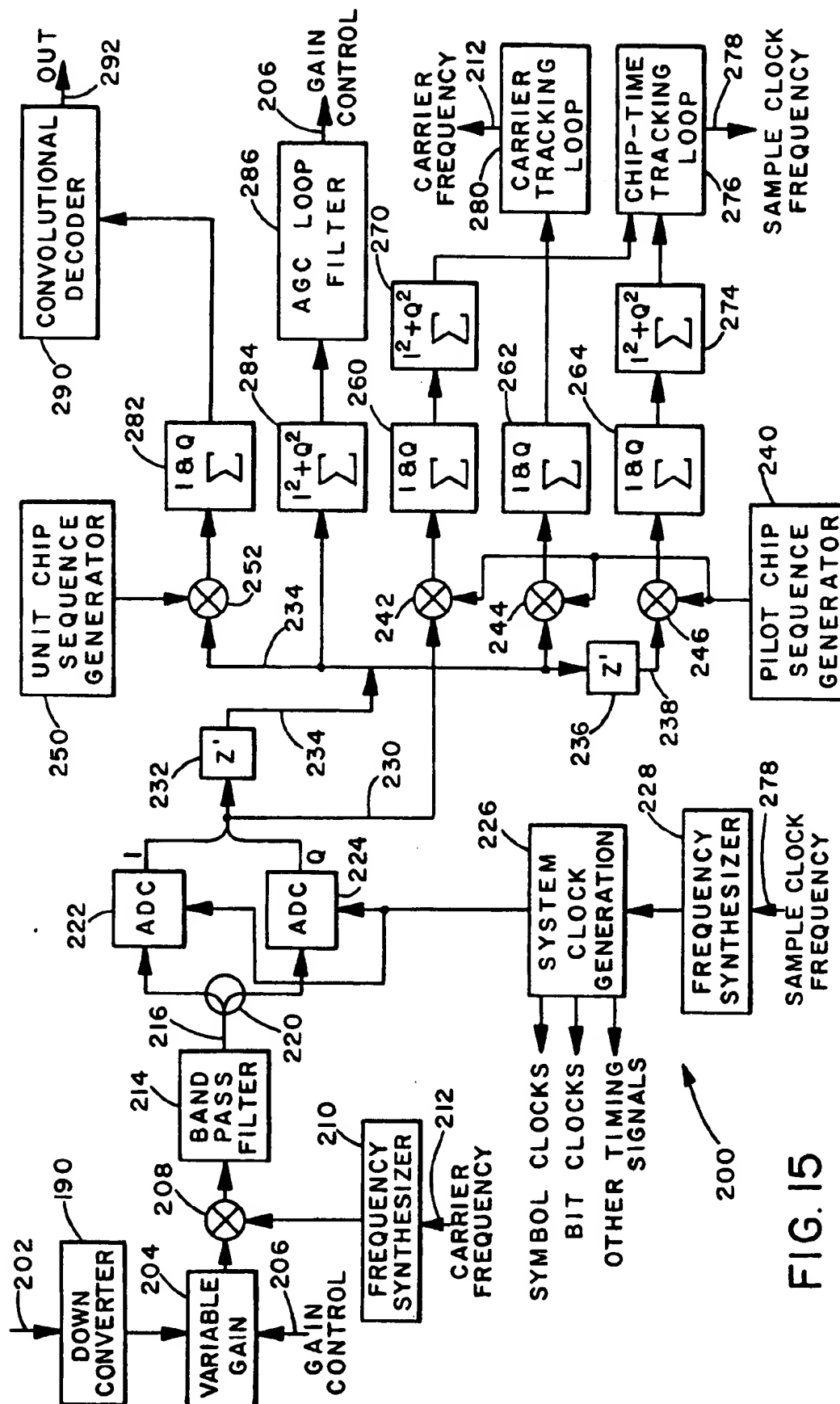


FIG. 15

